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DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 30

WATER RESOURCES OF THE LOWER PENINSULA OF MICHIGAN.—Lane

WASHINGTON
GOVERNMENT PRINTING OFFICE
1899

IRRIGATION REPORTS.

The following list contains the titles and brief descriptions of the principal reports relating to water supply and irrigation, prepared by the United States Geological Survey since 1890:

1890.

First Annual Report of the United States Irrigation Survey, 1890; octavo, 123 pp.

Printed as Part II, Irrigation, of the Tenth Annual Report of the United States Geological Survey, 1888-89. Contains a statement of the origin of the Irrigation Survey, a preliminary report on the organization and prosecution of the survey of the arid lands for purposes of irrigation, and report of work done during 1890.

1891.

Second Annual Report of the United States Irrigation Survey, 1891; octavo, 395 pp.

Published as Part II, Irrigation, of the Eleventh Annual Report of the United States Geological Survey, 1889-90. Contains a description of the hydrography of the arid region and of the engineering operations carried on by the Irrigation Survey during 1890; also the statement of the Director of the Survey to the House Committee on Irrigation, and other papers, including a bibliography of irrigation literature. Illustrated by 29 plates and 4 figures.

Third Annual Report of the United States Irrigation Survey, 1891; octavo, 576 pp.

Printed as Part II of the Twelfth Annual Report of the United States Geological Survey, 1890-91. Contains "Report upon the location and survey of reservoir sites during the fiscal year ended June 30, 1891," by A. H. Thompson; "Hydrography of the arid regions," by F. H. Newell; and "Irrigation in India," by Herbert M. Wilson. Illustrated by 93 plates and 191 figures.

Bulletins of the Eleventh Census of the United States upon irrigation, prepared by F. H. Newell; quarto.

No. 85, Irrigation in Arizona; No. 60, Irrigation in New Mexico; No. 85, Irrigation in Utah; No. 107, Irrigation in Wyoming; No. 153, Irrigation in Montana; No. 157, Irrigation in Idaho; No. 163, Irrigation in Nevada; No. 178, Irrigation in Oregon; No. 193, Artesian wells for irrigation; No. 198, Irrigation in Washington.

1892.

Irrigation of western United States, by F. H. Newell; extra census bulletin No. 33, September 9, 1892; quarto, 22 pp.

Contains tabulations showing the total number, average size, etc., of irrigated holdings, the total area and average size of irrigated farms in the subhumid regions, the percentage of number of farms irrigated, character of crops, value of irrigated lands, the average cost of irrigation, the investment and profits, together with a résumé of the water supply and a description of irrigation by artesian wells. Illustrated by colored maps showing the location and relative extent of the irrigated areas.

1893.

Thirteenth Annual Report of the United States Geological Survey, 1891-92, Part III, Irrigation, 1893; octavo, 486 pp.

Consists of three papers: "Water supply for irrigation," by F. H. Newell; "American irrigation engineering" and "Engineering results of the Irrigation Survey," by Herbert M. Wilson; and "Construction of topographic maps and selection and survey of reservoir sites," by A. H. Thompson. Illustrated by 77 plates and 119 figures.

A geological reconnoissance in central Washington, by Israel Cook Russell, 1893; octavo, 108 pp., 15 plates. Bulletin No. 108 of the United States Geological Survey; price, 15 cents.

Contains a description of the examination of the geologic structure in and adjacent to the drainage basin of Yakima River and the great plains of the Columbia to the east of this area, with special reference to the occurrence of artesian waters.

1894.

Report on agriculture by irrigation in the western part of the United States at the Eleventh Census, 1890, by F. H. Newell, 1894; quarto, 283 pp.

Consists of a general description of the condition of irrigation in the United States, the area irrigated, cost of works, their value and profits; also describes the water supply, the value of water, of artesian wells, reservoirs, and other details; then takes up each State and Territory in order, giving a general description of the condition of agriculture by irrigation, and discusses the physical conditions and local peculiarities in each county.

Fourteenth Annual Report of the United States Geological Survey, 1892-93, Part II, Accompanying papers, 1894; octavo, 597 pp.

Contains papers on "Potable waters of the eastern United States," by W. J. McGee; "Natural mineral waters of the United States," by A. C. Peale; and "Results of stream measurements," by F. H. Newell. Illustrated by maps and diagrams.

(Continued on third page of cover.)

DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 30

WASHINGTON
GOVERNMENT PRINTING OFFICE
1899

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR.

WATER RESOURCES

OF THE

LOWER PENINSULA OF MICHIGAN

BY

ALFRED C. LANE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1899

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, April 14, 1899.

SIR: I have the honor to transmit herewith a manuscript on the Water Resources of the Lower Peninsula of Michigan, by Dr. Alfred C. Lane, and to recommend that it be printed as one of the series of Water-Supply and Irrigation Papers. This material is a portion of the outcome of Dr. Lane's studies in connection with the geological survey of the State of Michigan, supplemented by statements received in reply to circulars sent throughout the Lower Peninsula of Michigan to well drillers and others likely to be well informed and interested in the subject. The facts thus gathered have been collated with the result of two months' field work during the autumn of 1897. The complete report has assumed such bulk that it has been found necessary to divide it into several parts. The first of these, containing the general conclusions, is herewith presented. The remaining data fall naturally into two classes, the first consisting of analyses of waters and the second of detailed descriptions of the supply at various localities visited. It is hoped that these data may be printed as succeeding papers of this series.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

WATER RESOURCES OF THE LOWER PENINSULA OF MICHIGAN.

By ALFRED C. LANE.

VARIOUS USES OF WATER.

The region under consideration is generously endowed with water supplies, but it is apparent from experience elsewhere that these may be wasted or seriously depreciated in value by carelessness or lack of knowledge of their extent and limitations. It is a common error to suppose that if the limit to the supply of anything is not clearly in sight that the supply is inexhaustible; for example, the "practically inexhaustible" supplies of pine of the Saginaw Valley of thirty years ago are now nearly gone, and instances are cited of the sale of privileges of cutting the stumps on land already cut over for sums greater than the tracts originally cost. "Inexhaustible supplies" of natural gas have failed; and, in short, it may be said that there is hardly a natural resource whose quantity or quality has not seriously deteriorated through lavish use.

In many parts of the United States formerly as well watered as Michigan there has been apparently a shrinkage of water supply. The streams which at one time carried considerable volumes of water throughout the year are now reported to be, during summer at least, nearly dry. Flowing wells have failed in many regions, either from faulty construction or from the multiplication of deep borings. In order, therefore, that it may be possible not only to utilize the water resources of the area under discussion to the fullest possible extent, but also to guard against causes of failure, it is desirable to bring together all of the information available, combining the facts and drawing broad conclusions.

Although the uses of water are almost infinitely varied, yet all kinds of water are not equally available for all purposes. The wide range in the quantity of water and in its quality leads to an equal diversity in application; for example, Michigan, as a whole, being humid, water has little value for agriculture, irrigation being practically confined to the use of water from city supplies applied to lawns, flower beds, and rarely to fruit trees and market gardens. On the other hand,

although water is so abundant consideration must be paid to its quality; that is, to the amount and kind of organic or inorganic matter held in solution or suspension. Another matter of primary importance is the elevation of the water with reference to possible fall, or, in other words, the head available. Upon this latter feature depends whether it can be used as a source of power or whether power must be consumed in raising it.

For certain uses practically the only thing desired is abundance of supply; for example, such city uses as fire protection, flushing sewers, and cleaning streets. The head required is generally obtained artificially. Only in exceptionally favored localities, such, for example, as those close to the edge of the moraine country on the lakeward side, is there head sufficient to obviate the use of pumps. This is the case in Hart, T. 15 N., R. 17 W.; Rochester, T. 3 N., R. 11 E.; and Rose, T. 24 N., R. 3 E.

There are other uses, however, in which quality is the first consideration; as, for instance, cooking and drinking. Finally, as a source of power water must, of course, have head.

Thus the different sources of supply and the different uses have been classified, so that one may see at a glance the more important factors in a given use and the sources which best meet the requirements. The most difficult problems to solve, however, are those where many needs are to be met by one system; where, as in a supply for a city, it is frequently necessary that ample quantity for fire protection and hose use should be combined with at least a good degree of organic purity for drinking purposes and, if possible, with sufficient purity from lime and inorganic salts to be available for laundry use and for boilers. Such cases require special consideration and often present very complex problems.

USES WHERE QUANTITY IS IMPORTANT.

TRANSPORTATION ON THE GREAT LAKES.

The great extent of shore line and the use of the waters of the State for transportation require some notice, especially in their bearing on other water uses. Michigan is more cut up by the Great Lakes than any other State, having some 1,600 miles of shore line, and the commerce on the Lakes is growing at a remarkable rate. The commerce past Detroit is greater than that past any other port in the world The harbor master of Sand Beach estimates that a boat passes within sight every five minutes, day and night.

If commerce increases in the future as in the past, it may be doubtful whether the Great Lakes, and rivers like the St. Clair and Detroit, independent of the question of sewage emptied into them, will be sufficiently free from organic impurities to be available for city water supplies. At present the Great Lakes are the source of the water supply of most of the cities and towns on their shores.

NAVIGATION ON THE SMALLER LAKES AND RIVERS.

On many of the larger inland lakes, in which Michigan is so rich, and on some rivers tugs have been employed, mainly for pleasure or for towing logs. The lower parts of the rivers are used for harbors. Along the west shore, as at Manistee, Ludington, and Frankfort, the lower reaches of all the rivers are practically lakes. These lakes are separated from Lake Michigan by sand bars, which often have to be cut, after which the lakes make good small harbors. In this way Charlevoix Harbor has been connected with Pine Lake by a short cut, and Cheboygan is located on a river the mouth of which serves as a harbor. In the part of the State lying between Traverse City and Cheboygan it has been possible, with some artificial aid, to establish an extensive system of inland navigation. It may be noted, too, that for a long distance from its mouth the Saginaw River and its various branches are practically at lake level. In fact the watershed between the Grand River and the Saginaw, near Ashley, is only about 87 feet above the lake level, so that if, as has been suggested, a canal were to be built to cut off the long northern voyage by the Straits of Mackinac from Chicago and Milwaukee, it would be far easier to construct it along this line than any other. On the Michigan side Grand River is navigable nearly to Grand Rapids. Besides Saginaw River up to St. Charles, the mouths of Black River at Port Huron, of Thunder Bay River at Alpena, and of Huron River are used for short distances. Transportation by boat has, however, been checked along Saginaw River and other streams by their extensive use for the transportation of logs, to say nothing of the fact that they are very crooked.

LOG DRIVING.

A glance at the map will show that the branches of the Saginaw diverge in every direction, from north-northeast to east-northeast, and they have served to transport the pines to Saginaw and Bay City. For miles along their course the rivers have been packed solid with logs. Lumbermen's dams have been constructed along the headwaters, their object being to accentuate and regulate the floods. The Saginaw Valley has now, however, been converted into farming country, and Saginaw has its city water supply—which, fortunately, is not much used for drinking—from these rivers. In considering the use of the Saginaw and its branches for such purposes the fact must not be forgotten that for a large part of the year they are stagnant water, with the current setting up and down with the changes in the wind and in the level of the bay, and that they are lined with rotting logs. It is no wonder that the analyses of such streams show much organic matter. There are all along the shores of the peninsula, at the mouths of the more important streams, towns of considerable size which obtained their start as sawmill towns and which are, or were, supported

by the occupation of turning the logs floated down to them into merchantable lumber. The size of such towns is roughly proportional to the drainage area of the streams which furnish them their raw material and supply them with harbors.

CITY USES.

One of the most important uses of water is as a protection against fire, and this use has, indeed, called into existence most of the city water supplies. Many towns—e. g., Weston (T. 8 S., R. 3 E.) and Grayling (T. 26 N., R. 3 W.)—now have their water supply in this first stage of development.

Michigan towns are invariably built of wood, at least at first, and even the largest cities are composed chiefly of wooden buildings. Fire protection is consequently essential to the existence of the cities. Saginaw, Cheboygan, Ontonagon, and Bad Axe are but a few of the towns that have been devastated by fire. For fire protection the prerequisite is an ample supply of water. The necessary head is nearly always obtained artificially, partly by the use of steam pumps and partly by fire engines. A few of the smaller towns have sufficient natural head.

To insure an ample supply of water the fluctuations of level of the water surface must be taken into consideration, and not merely the seasonal fluctuations, but, if the Great Lakes are drawn on, the sudden fluctuations to which they are peculiarly subject. The Saginaw River and its branches, as has been said, are at lake level and subject to these fluctuations, the current running sometimes upstream and sometimes downstream. As the present waterworks are arranged, the water for both East and West Saginaw is taken from settling basins, and on at least one occasion, in the fall of 1895,[1] the level was lowered dangerously near that of the intake pipe. If water should fail in the midst of a fire like that which, on May 20, 1893, in a few hours destroyed property to the value of $650,000, the city would be practically destroyed. There is more than a mere chance of this coincidence, for, as will be shown later, low water may be caused by strong southwest winds. Such warm, dry, strong winds are likely to occur. In fact, such a wind is said to have been blowing 50 miles an hour at the time of the fire just mentioned. If a dam were built across the river so as to check the reversal of its current, it would not only guard against this danger but would prevent the carriage of the sewage of the city into the water supply. The water of the regular supply at Saginaw is not fit to drink unless it is boiled or filtered, and the city has drilled 29 wells to the underlying sandstones in order to obtain water suitable for drinking.

The possibility of retreat below the level of intake is probably the only danger to be guarded against in the use of lakes and rivers for

[1] See Annual Report of Water Board of East Saginaw, 1896, p. 10.

water supply for fire protection. The fluctuations of mean lake level have been about 7 feet during the century. To allow for exceptional low water due to strong winds, it would be well to have intake pipes at least 10 feet below high-water level.

Almost all kinds of wells are likely to fail to satisfy the demands of the large towns, and one hears continually, in towns that are supplied from wells, of steps taken to procure more water. Often where the water supply is from wells, as at Mount Pleasant, the plant is so arranged that in fire emergency use may be made of some additional body of water for supplementary supply. But in such a case the water should be taken through a filter gallery, as otherwise there will be constant suspicion and complaint that the engineer is substituting the inferior supply, which of course he should not do without warning.

However, the demand on a public water supply is very heavy, and in this demand the use of water with the garden hose, the only form of irrigation prevalent in Michigan, is no inconsiderable factor. Almost universally where a city water supply exists it is used with hose upon lawns and gardens. This use is generally lavish, though not infrequently checked somewhat by regulations limiting the use to certain hours, prohibiting the use of sprinklers all night, etc. Thus, in Saginaw, where the city water supply is little used for drinking, an average of 6,678,651 gallons a day were pumped in the year ending February 29, 1896, which, for a population of 45,000 (18,000 users), is more than 148 (371) gallons per capita, a quantity much larger than has been considered necessary in England, viz, 30 gallons a day per capita; and, as we have just said, well water is very largely used for domestic purposes. In East Saginaw, in the same year, 313,705,672 gallons were pumped in June and July, against 263,225,916 in April and May (hours of fire pressure 26½ to 18), while in West Saginaw the corresponding figures are 158,018,960 and 132,089,771 (hours of fire pressure 14 to 13), showing an increase of nearly 20 per cent in summer use, largely through the use of garden hose. Besides these there are other considerable city uses—flushing sewers and urinals, washing sidewalks, windows, and streets, running water motors, etc. For all these the quality of the water is comparatively unimportant. Indeed, the very sewage matter which renders it unfit for drinking, and the sulphates and carbonates of lime which render it less available for laundry and boiler use, are an advantage, rather than otherwise, when sprinkled on gardens. The difficulty in city water supply arises in the antagonism of these two classes of uses—those which demand an indefinitely large supply regardless of quality, and those which require a high degree of purity. Michigan cities usually consume 100 to 200 gallons a day for each inhabitant. The introduction of meters would result in some saving. The use of garden hose is often lavish and in violation of rules. The use of a meter should be compulsory where garden hose is employed. Unfortunately,

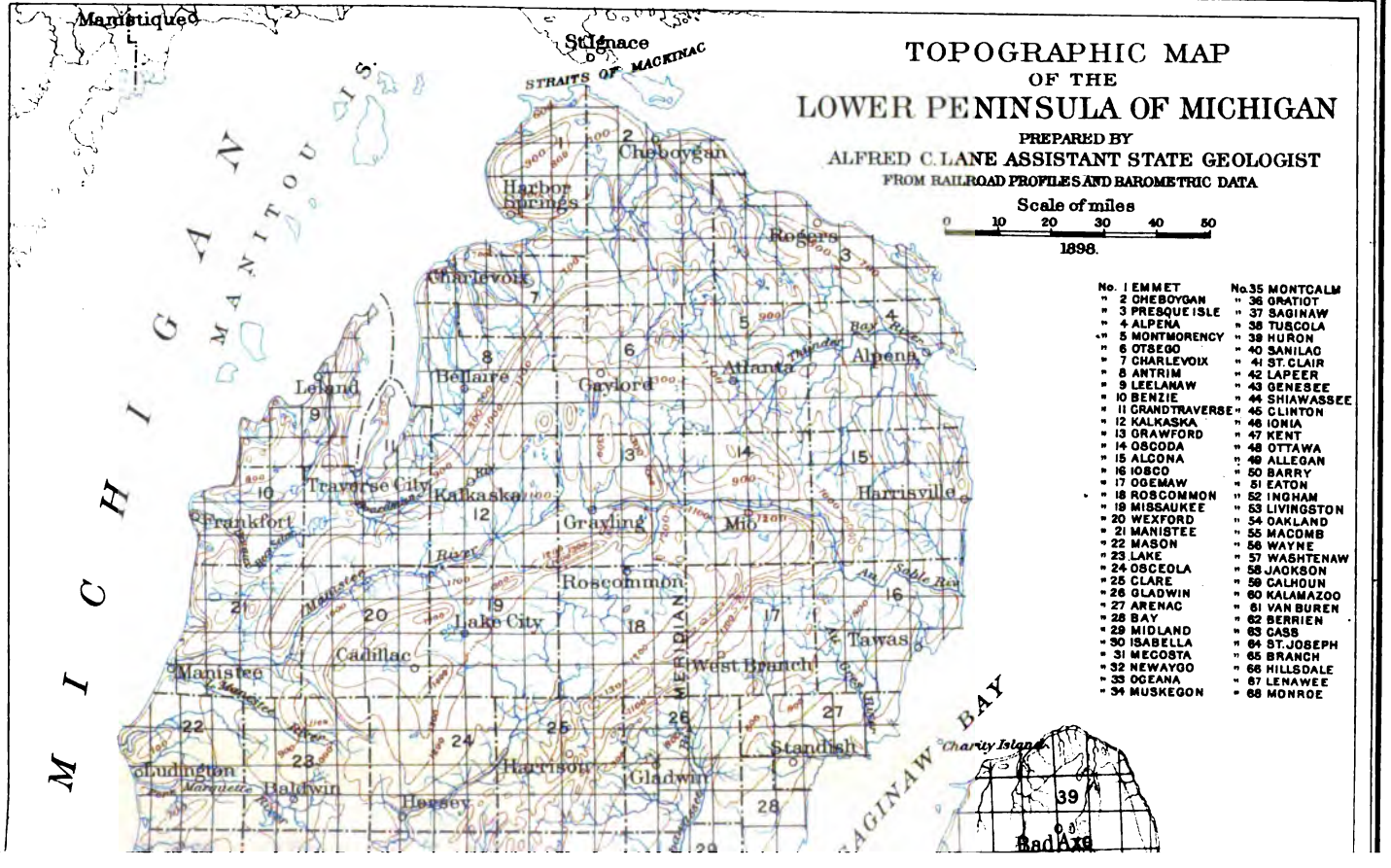
the need of quantity has too often been considered alone, and even the most rudimentary precautions for purity have been neglected.

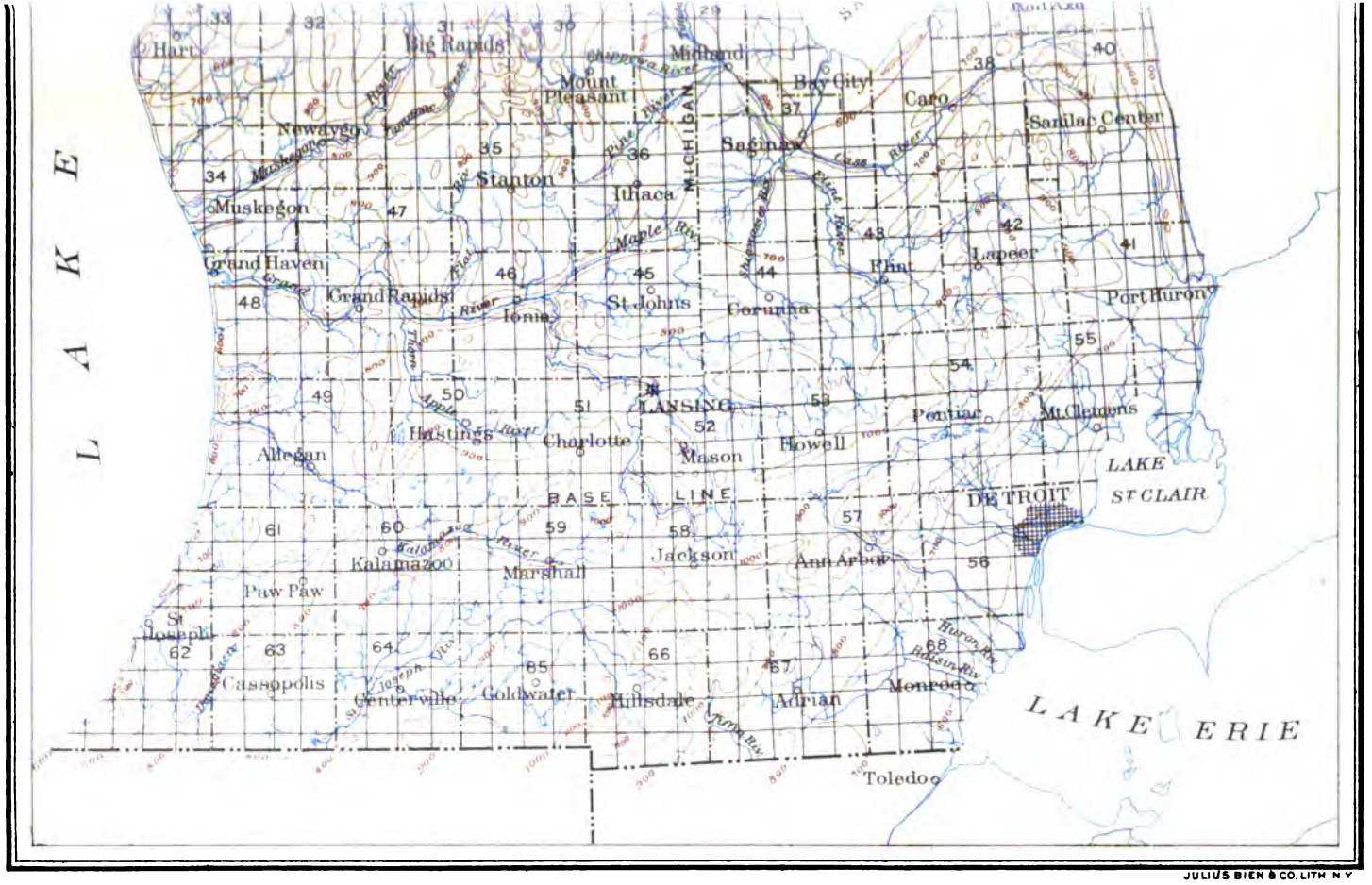
West Saginaw takes its water direct from the river, under a dock close to the heart of the city and near a large sewer, the settling tank being 75 by 22 feet and the river current variable. The water is of a muddy-green color, with a good deal of bark floating around in the tank. Alma takes water from a mill race 300 feet above a sewer. There is no protection to the banks of the stream above. Both of these places, however, use almost exclusively for drinking purposes water from deep wells which comes under clay and is therefore safe. In Saginaw it is said that the salt water from the deeper wells has found its way into some of the shallower rock wells and contaminated them, and the waste bitterns go into the river. But individual wells, however numerous, are not an ideal supply for a large town, with the running here and there to neighbors, the possibility of some wells being too shallow to be safe, and the liability to contamination from dug wells. The Saginaw is so sluggish a stream that it is practically a pond. A plant situated as far up as the East Saginaw plant, therefore, if the banks were bought for a "riverside park" and protected for a few miles, and if the reflux of water from the lower river were prevented, especially if there were a gravel bed instead of decaying planks between the settling tank and the river, might furnish a fairly satisfactory water supply; but one would probably not have to go far—not beyond Vassar—to secure an ample and pure supply in sandstone. Analyses of these waters will be given in a later paper. Most of the other large cities are supplied from the Great Lakes, and seem to find no objection to that source, though Chicago's experience shows that there is a possibility of danger to be guarded against.

Many towns, however, like Rochester, Birmingham, Hunt, Petoskey, Charlevoix, Harbor Springs, Bay View, and Cheboygan have found a sufficient supply in deep wells, and most towns of the State could be thus supplied if they were willing to give up the use for garden hose, motors, etc. The construction of a large reservoir to meet the extra heavy demand of summer might be feasible. One practicable way would be to limit the use of garden hose to a short time each day, during which time the reservoir or some inferior filtered source of supply could be drawn upon. It is an advantage of this plan that the efficacy of a gravel filter bed is immensely increased if it is not continuously in use.

The use of water in our Michigan towns is extravagant, and the difficulty of securing a proper quality is correspondingly increased. For example, Bay City, with a population of about 33,000, besides the supply from wells, in 1896 used 197 gallons a day, about 5 per cent of which was through manufacturing meters, 5 per cent through domestic meters, and the rest at fixed rates. The special water supply committee of the city council of Traverse City, 1897, George W.

1


TOPOGRAPHIC MAP
OF THE
LOWER PENINSULA OF MICHIGAN
PREPARED BY
ALFRED C. LANE ASSISTANT STATE GEOLOGIST
FROM RAILROAD PROFILES AND BAROMETRIC DATA
Scale of miles
0 10 20 30 40 50
1898.
No. 1 EMMET
" 2 CHEBOYGAN
" 3 PRESQUE ISLE
" 4 ALPENA
" 5 MONTMORENCY
" 6 OTSEGO
" 7 CHARLEVOIX
" 8 ANTRIM
" 9 LEELANAW
" 10 BENZIE
" 11 GRANDTRAVERSE
" 12 KALKASKA
" 13 CRAWFORD
" 14 OSCODA
" 15 ALCONA
" 16 IOSCO
" 17 OGEMAW
" 18 ROSCOMMON
" 19 MISSAUKEE
" 20 WEXFORD
" 21 MANISTEE
" 22 MASON
" 23 LAKE
" 24 OSCEOLA
" 25 CLARE
" 26 GLADWIN
" 27 ARENAC
" 28 BAY
" 29 MIDLAND
" 30 ISABELLA
" 31 MECOSTA
" 32 NEWAYGO
" 33 OCEANA
" 34 MUSKEGON
No. 35 MONTCALM
" 36 GRATIOT
" 37 SAGINAW
" 38 TUSCOLA
" 39 HURON
" 40 SANILAC
" 41 ST. CLAIR
" 42 LAPEER
" 43 GENESEE
" 44 SHIAWASSEE
" 45 CLINTON
" 46 IONIA
" 47 KENT
" 48 OTTAWA
" 49 ALLEGAN
" 50 BARRY
" 51 EATON
" 52 INGHAM
" 53 LIVINGSTON
" 54 OAKLAND
" 55 MACOMB
" 56 WAYNE
" 57 WASHTENAW
" 58 JACKSON
" 59 CALHOUN
" 60 KALAMAZOO
" 61 VAN BUREN
" 62 BERRIEN
" 63 CASS
" 64 ST. JOSEPH
" 65 BRANCH
" 66 HILLSDALE
" 67 LENAWEE
" 68 MONROE
Manistique
St. Ignace
STRAITS OF MACKINAC
MICHIGAN
MANITOU IS.
Cheboygan
Harbor Springs
Rogers
Charlevoix
Bellaire
Gaylord
Atlanta
Alpena
Leland
Traverse City
Kalkaska
Harrisville
Frankfort
Grayling
Mio
Roscommon
Lake City
Cadillac
Tawas
Manistee
West Branch
MERIDIAN
Standish
Ludington
Baldwin
Harrison
Gladwin
Hersey
SAGINAW BAY
Charity Island
Bad Axe



JULIUS BIEN & CO. LITH. N.Y.

Rafter, consulting engineer, figured upon supplying 100 gallons a day to a population three times the present. This is one of the most carefully studied of recent propositions and the report compares a number of typical city sources of supply.

USES WHERE HEAD IS IMPORTANT.

The use of water for motive power depends not only on the quantity, but also on the head. The total energy is expressed by the product of these two. There are two widely different conditions under which water is thus used. The one is where the head is first artificially obtained and the water is raised by pumping. In such cases the water acts merely as a distributor of power. In this way water is used in many of the cities and towns, running motors for light machinery, especially for elevators. The chief advantages are that it is ready at hand, quiet, noiseless, odorless, not dangerous, and convenient in every way. There is, however, considerable loss of head in narrow and crooked pipes, and it is not the most economical method of transmitting power, while the extra quantity of water needed makes the attainment of desirable quality far more difficult. Electricity may be expected to relieve our water systems of much of this burden of power transmission. The other use is where natural water power is utilized. In respect to natural water power, Michigan is much better situated than many adjacent States, though there are no very large streams except the international Detroit and St. Clair rivers, which are not dammed.

A large area, both in the northern and southern part of the State, is more than 1,000 feet above tide, or say 400 feet above lake level. It will be noticed, too, from the contour map (Pl. I) and from fig. 10 that the descent from the 1,000 to the 700-foot contour line is frequently quite rapid, and here is a great belt of water powers.

In a few cases, as at Traverse City and around West Branch, flowing wells furnish such a volume of water as to be of considerable power. Around West Branch and Rose City such wells distribute water into the second stories of the houses, and at Traverse City, as at Harbor Springs, it has been proposed to use part of the water in a hydraulic ram to elevate the remainder.

But the head of flowing wells is of most importance in saving the power, windmill or steam, which would otherwise be required to elevate the water.

There are also many lakes—and these chiefly in the highest parts of the State—which help to steady the flow of the streams by acting as reservoirs, though many of them are quite variable in their water stage. For instance, Clam Lake, near Cadillac, is said to have varied more than 16 feet. Thus conditions are quite favorable to the development of water power in streams, and small water powers, suited for village waterworks, electric-light plants, country sawmills

and gristmills, etc., are widely distributed along the edge of and in the morainal areas. Almost uniformly wherever, as explained later (p. 63), the earlier high-level Glacial drainage has been captured and diverted by streams which have worked back across the moraines, good sites for water powers may be found, though thus far the abundance of fuel and the relatively heavy first cost of waterworks improvements have retarded their development somewhat.

WATER POWERS IN MICHIGAN.

The following table of places where water powers have been observed or reported is doubtless very incomplete. More complete accounts are given of the two important regions which have been studied in greater detail. The southeastern part has been studied in connection with the Tenth Census, and Kalamazoo River has been studied by Mr. Robert E. Horton. It must not by any means be inferred that the Huron and the Kalamazoo are, from the importance given to them, the most important water-power streams of the State. They are merely those of which the most is known, and the study of the Grand River system, and others equally important in the northern part of the State, would require more time and money than have been allotted to this paper.

Water powers in Michigan.

Stream.	Location of power.	Remarks.
LAKE ERIE DRAINAGE.		
Raisin River	Few above Adrian	
Huron River	Dexter to Ypsilanti, mainly.	See Report on Water Powers, Tenth Census. See also Winchell, Geology of Washtenaw County, 1881, p. 19.
Do	Ypsilanti (5-foot fall)	Water power for waterworks pumping station.
Do		Grist mill. About 10-foot fall.
Do		Underwear factory.
Do	Pettibone mills, Milford	Paper mill.
Tiffin River	Below Hudson	Small.
DETROIT RIVER DRAINAGE.		
River Rouge (Ecorce River).	Northville	Above Plymouth; small flow, considerable fall.
LAKE ST. CLAIR DRAINAGE.		
Clinton River	Rochester	Above Utica are numerous small powers.

Water powers in Michigan—Continued.

ST. CLAIR RIVER DRAINAGE.

Stream.	Location of power.	Remarks.
Belle River		
Mill Creek	Below Yale	
Black River		Poor power; a stream of diminishing drainage area; swamps being cleared and summer drought becoming accentuated.

THUMB OF MICHIGAN.

Allen Creek	Rock Falls	10-foot head; not much water; abandoned.
Willow River	Huron	Abandoned.
Pinnebog River	Near Popple	Not used; drainage area growing, but the swamps are being cleared.
Pigeon River	Above Wolfton	Not used.

SAGINAW RIVER DRAINAGE.

Cass River		A stream of diminishing drainage and sandy course.
Do	Caro	Undeveloped.
Do	Vassar	4-foot fall.
Flint River	Flint to Columbiaville	Good power near Flint.
Shiawassee River	Owosso	
Do	Corunna	10-foot fall.
Pine River	St. Louis and Alma, up to Millbrook.	At St. Louis dam; at Alma a dam with 10-foot head helps run elevator and waterworks.
Chippewa River	Mount Pleasant	15-foot fall runs waterworks, electric-light plant, and elevator.
Do	Barryton	Dam; 8-foot fall.
Salt River		
Tobacco River	Farwell and Clare	
Tittabawassee River		Very sandy and sluggish, except at head waters.

Water powers in Michigan—Continued.

LAKE HURON DRAINAGE NORTH OF SAGINAW RIVER.

Stream.	Location of power.	Remarks.
Rifle River		Good mill stream.
Houghton Creek	Rose City	10-foot dam.
Au Gres River		Small stream, with considerable valleys and fall where crossing the 200-foot contour line.
Au Sable River	Especially through the stretch from Mio to T. 24 N., R. 6 E.	Splendid water powers; unused, largely fed by springs, with a comparatively small flood plain.
Do	Grayling	Dam.
Thunder Bay River	Alpena. Numerous	Brodwell's mills and Trowbridge's mills.
Cheboygan River	Long Rapids to Hillman.	Little fall.
Oqueoc River		
Sturgeon River	Sec. 3, T. 34 N., R. 1 E.	Mill.
Rainy River		Probably some powers; rock banks.
Pigeon River		
Mulletts River	Wolverine to Trowbridge.	

LAKE MICHIGAN DRAINAGE.

Bear River	Petoskey	Ingalls mills.
Boyne River	Boyne Falls	Other similar small streams to southwest.
Elk River	Elk Rapids	Wing dam and undershot wheel; put in as early as 1850; note the very large lake drainage; steady power.
Duck Lake	Outlet	9-foot fall; 60–70 horsepower used.
Boardman River		Variable; near Traverse City 20-foot head; flow in drought about 100 cubic feet a second. See p. 31.
Carp River		Outlet of Carp Lake; 5 to 6 foot fall.
Betsie River	Weldon Township	
Do	Benzonia	

Water powers in Michigan—Continued.

LAKE MICHIGAN DRAINAGE—Continued.

Stream.	Location of power.	Remarks.
Crystal Creek	Outlet of Glen Lake	2 or 3 powers.
Manistee River	Lower part	Sandy valley; drainage area diminishing; numerous small mill sites; quite variable.
South Branch		Rapid fall below Tustin.
Little Manistee River		
Big Sable River		
Notepeakan River		
White River		
Muskegon River	Newaygo	
Do	Big Rapids	30-foot fall; large stream; steadied inflow by lakes and springs; furniture factories, etc.
Crockery Creek		
Rabbit River		
Kalamazoo River		See report by Robert E. Horton, pp. 22–38.
Coldwater River		
Hog Creek		
Fawn River	Near Burrows	
Grand River	Grand Rapids	Large manufacturing power.
Flat River	Fallassburg	85-foot fall between here and at Lowell.
Rouge River		
Bear Creek	Cannon, T. 8 N., R. 10 W	200-foot fall in 12 miles.
Apple Creek	Caledonia, T. 5 N., R. 10 W.	
Do	Alpine, T. 8 N., R. 12 W	Tributaries of Grand River; mill sites in eastern part.
Thornapple River	Cascade, T. 6 N., R. 10 W	Fine water power.
Do	Whitneyville	
Cedar Creek		Good mill stream.
Do	Ada	Two mills.
Buck Creek		Mill stream.
Grand River	Grand Ledge	Factories. There are numerous small powers among the headwaters of the Grand.
Do	North Lansing	9-foot fall. Also a dam at South Lansing.
Do	Eaton Rapids	

Water powers in Michigan—Continued.

LAKE MICHIGAN DRAINAGE—Continued.

Stream.	Location of power.	Remarks.
Grand River	Jackson	Dams; about 10-foot head.
Paw Paw River	Almena, T. 2 S., R 13 W	Spring Brook, one of the headwaters, has 18-foot head running a saw and feed mill, about 821 cubic feet a day; lowers 5 or 6 inches a day, but fills up over night. The brook starts in a big spring 1 mile away and passes through two lakes. Adjacent brooks furnish similar powers of local value.

REPORT ON THE RUN-OFF AND WATER POWER OF KALAMAZOO RIVER.

By Robert E. Horton.

GEOLOGY AND TOPOGRAPHY.

The Kalamazoo River rises in the south central part of the Lower Peninsula of Michigan and flows in a northwesterly direction, debouching into Lake Michigan 3¼ miles below the village of Saugatuck. Its current is slow, averaging about 3 miles an hour, and its slope uniform, there being no waterfalls and no considerable rapids except at two points, at each of which there occurs a descent of 3 or 4 feet within a distance of a few rods. The river flows through a rich agricultural region, in a valley from one-fourth of a mile to 2 or 3 miles in width, backed by low hills or sloping gently to the upland. The flat lands in the valley are often flooded and serve largely as permanent meadows through which the river winds, often in a very tortuous manner. Two branches unite at Albion to form the main stream. The total length from the point of juncture to the outlet is 101 miles.

In respect to the climate, topography, and run-off of its watershed Kalamazoo River may be considered as typical of the larger streams of southern Michigan, including the Grand, the St. Joseph, and the Raisin, all of which find their sources within a few miles of each other and of the Kalamazoo. The drainage area covers 1,750 square miles overlaid with Pleistocene deposits. The surface formations are distributed about as follows: Morainal ridge and glacial drift covers between 25 and 45 per cent of the watershed; clay-loam till plains, 25

to 35 per cent; overwash valley train deposits of the ice drainage, 35 to 45 per cent. The latter lies chiefly in the middle and upper portions of the watershed, underlying short tributaries with swamp drainage. The clay-loam till plains form basins for lake storage, but give small flow from ground storage. The surface soil is diversified. Gravel, clay, and loam, mixed with sand, alternate in relatively small areas.[1]

Between Albion and Augusta, a distance of 34 miles, the main river channel lies between parallel morainal ridges deposited by the east wing of a reentrant cusp of the ice front which had at one time worked back step by step from the Indiana line. Between Kalamazoo and Plainwell the river channel cuts through the more northerly of these parallel ridges. The Valparaiso moraine and Covert ridge, running parallel to the above and to the lake front, are similarly crossed below Otsego.

The main river below Kalamazoo largely follows lines of pre-Glacial drainage. In the upper portion of the watershed the tributaries, which are numerous and ramify extensively, generally disregard the morainal contours in their courses, while the main stream follows them closely. There is a fall of from 12 to 20 feet, within a distance of about a mile, at the point of discharge of a number of tributaries, furnishing excellent water powers at points where the extent of the flats prevents dams being built on the main river.

The depths in feet, as determined from deep borings of the drift sand and shale deposits underlying the river channel at various points along its course, are as follows:[2]

Sections below channel of Kalamazoo River.

Place.	Distance from mouth of stream.	Depth of glacial drift.	Depth of sand rock.	Depth of blue shales below sand rock. *a*
	Miles.	*Feet.*	*Feet.*	*Feet.*
Albion	101	10	271	100
Marengo	93	60	200	200
Marshall	88.8	70	43	327
Battle Creek	75.5	70	43	320
Kalamazoo	52.1	130	(*b*)	(*b*)
Allegan	32.5	260	75	770

a As far as measured. *b* Together, 1,070 feet.

The line of the supposed outcrop of the bottom of the Marshall sandstone crosses the watershed in a northwesterly and southeasterly direction, intersecting the river channel below Battle Creek.

[1] See effect of drift upon topography and drainage, by Frank Leverett: Seventeenth Ann. Rept. U. S. Geol. Survey, Part II, pp. 706-711.

[2] The geology of Lower Michigan with reference to deep borings: Geol. Survey Michigan, Vol. V, Part II.

There are, within the catchment basin, a large number of small lakes and spring hollows, in which water stands part or all of the time. Many of these have no surface outlets and feed the stream only through seepage or ground flow, a large portion of their waters being consumed directly by evaporation. Each of these lakes drains an area varying generally from six to twelve times its own area, and their combined catchment reduces materially the area directly tributary to the river. The following table shows the relative number and area of tributary and nontributary lakes within the watershed in the four counties having the largest tributary drainage:[1]

Tributary and nontributary lakes in the watershed of Kalamazoo River.

County.	Drainage of river.	Number of tributary lakes over ¼ mile in diameter.	Area of tributary lakes.	Number of nontributary lakes within drainage area.	Area of nontributary lakes.
	Sq. miles.		*Sq. miles.*		*Sq. miles.*
Calhoun	486.68	58	3.69	47	2.95
Jackson	148.5	21	1.29	38	0.32
Kalamazoo	273.5	39	5.29	31	2.25
Allegan	687.	65	6.59	25	.64

It will be seen that most of the lakes are tributary. About 1½ per cent of the drainage area is lake surface. Probably 5 or 6 per cent drains into nontributary lakes.

The surface of the watershed is rolling. Prairie, swamp, and hilly stretches alternate at short intervals. Many lakes and a considerable area of swamp lands have been made to yield their waters directly to the stream through drainage.[2] To what extent the diminution of lake and swamp storage and of forested areas for the purposes of agriculture has been detrimental to the flow of the stream and to its value for water power can only be inferred. The oldest mill owners and water-power users strongly maintain that the river yields less power than formerly, holding that the flow is less uniform and the volume appreciably smaller than in pioneer days.

[1] These data have been obtained chiefly from atlases of the various counties.

[2] The problem of swamp drainage has been carefully studied. Peppermint and celery are largely grown on drained areas. See Michigan Engineer's Annual; Drainage engineering, by R. C. Carpenter: Proc. Michigan Engineering Society, 1882, pp. 40-48; Drainage of large marshes, by C. E. Hamilton: Proc. Mich. Eng. Soc., 1884, pp. 15-19; Reclamation of swamp lands, by O. H. Todd: Proc. Mich. Eng. Soc., 1894, pp. 57-66.

The distribution of cultivated, forest, meadow, and swamp areas in the watershed is as follows:[1]

Character of watershed of Kalamazoo River.

	Per cent.
Improved tilled land, including meadow and grass in rotation	60
Permanent meadows, pastures, orchards, etc	7
Woodland and forest	11
Undetermined, including waste swamp, lakes, building plats, villages, etc	22
Total	100

The character of the vegetation is an important factor in determining the proportion of rainfall on a watershed which reaches the stream as run-off during the summer months. The distribution of the principal crops grown and the number of inches of water they will require on the entire watershed during the growing season, are shown in the following table:

Distribution of crops in the watershed of Kalamazoo River.

Crop.	Entire watershed covered in 1896. *a*	Water required during growing season. *b*	Water required on the entire watershed.
	Per cent.	*Inches.*	*Inches.*
Wheat	11.2	10.8	1.2
Corn	8.0	13.8	1.1
Oats	4.0	16.6	0.7
Rye	3.3	9.1	0.3
Potatoes	0.7	4.6	0.03
Beans	1.7	4.6	0.08
Hay	6.9	20.5	1.4
Gardens, barley, millet, mint, etc	10.0	*c* 15.0	1.5

a From Farm Statistics of Michigan, 1896, issued by the secretary of state, Lansing, Michigan, 1896, may be taken as an ordinary year.

b After Risler's data. See Report of State Engineer and Surveyor of New York for 1894, pp. 373-377.

c Average.

The length of the growing season has been taken as one hundred days, including the months of June, July, and August, and part of September. The average date of the first heavy or killing frost varies in different localites of the watershed. The limiting dates will usually be between September 25 and October 10. The inches of water required on the entire watershed has been obtained by multiplying the depth required by each crop by the percentage of the whole area covered. Comparing these with the former data the following amounts are obtained as the water requirements of vegetation during the growing season of an ordinary year.

[1] Deduced from acreage data given in census of Michigan, 1894, Vol. II, Table I.

	Inches.
Leading crops on tilled area	6.6
Permanent meadows, etc	1.1
Woodland and forest, 11 per cent at 4 inches	0.4
Add for areas not otherwise included	3.0
Total depth required by vegetation	11.1

RAINFALL AND METEOROLOGY.

In order to obtain the true mean rainfall of the watershed it would be necessary to have long contemporaneous records at stations uniformly distributed throughout the region. Rainfall records have been maintained within the Kalamazoo watershed at the stations, and for periods shown in the following table. Column 5 gives the average yearly rainfall at the station multiplied by the percentage of the entire watershed, which it may be fairly said to represent. In this way the mean annual rainfall of the entire watershed is found to be 33.87 inches. Toward the mouth of the stream the depth of the annual rainfall increases several inches.

Rainfall on watershed of Kalamazoo River. (*a*)

1 Station (proceeding downstream).	2 Years.	3 Mean annual rain and melted snow.	4 Proportion of watershed represented by each station.	5 Rainfall on entire watershed for each station.	6 Probable annual fluctuation.*b*
		Inches.	*Per cent.*	*Inches.*	*Inches.*
Hanover	1886–1896	32.89	8.33	1.10	± 4.2
Pulaski	1888–1891	28.54	4.16	1.19	3.8
Concord	1888–1892	29.89	5.56	1.63	2.8
Olivet	1888–1892, 1896	33.16	12.22	4.00	4.5
Marshall	1881–1892	35.70	6.39	2.28	2.0
North Marshall	1889–1896	30.28	3.75	1.14	4.3
Battle Creek	1876–1880, 1885, 1895, 1896.	29.18	11.22	3.35	4.4
Kalamazoo	1876–1896	36.45	20.40	7.42	4.0
Allegan	1890–1896	35.75	32.97	11.76	4.2

a The meteorological data used in this report have been supplied by Mr. C. F. Schneider, director Michigan weather service.

b Deduced from the records in accordance with the theory of probabilities by Peters's formula.

Inasmuch as the rainfall at a station for any year can not be less than the mean by an amount exceeding 100 per cent, but may be more than 200 per cent of the mean, one would expect to find slightly more dry years than wet years in a long rainfall record. Out of eighty yearly records used in the table, thirty-nine were above the station means and forty-one were below. The twenty-one year record at Kalamazoo showed twelve years below and nine years above the

mean The fluctuation from the mean for dry years, or, in other words, the severity of the drought, will be less than the average fluctuation from the mean for wet years, in proportion as the number of dry years is greater than the number of wet years. The variability or probable fluctuations of rainfall, in inches, for any single year above or below the mean is shown in column 6.

The best record of rainfall within the watershed is that at Kalamazoo, covering twenty-one years, from 1876 to 1896, inclusive. The distribution of the monthly rainfall and the temperature throughout the year at Kalamazoo are shown by the following table. The heaviest rainfall occurs in the months of May and June, but that in August is most variable. This is probably due to the prevalence of thunderstorms during that month, which is also a month of high mean temperature. January has the lowest mean temperature, the least precipitation, and the least variability.

Monthly rainfall and temperature at Kalamazoo.

Month.	1 Mean monthly rainfall and melted snow.	2 Proportion of the mean yearly rainfall.	3 Probable fluctuation above or below the mean for a single year.	4 Mean monthly temperature at Kalamazoo. a
	Inches.	*Per cent.*	*Inches.*	° *F.*
January	2.24	6.2	0.63	23.06
February	2.40	6.6	0.92	25.45
March	2.42	6.7	1.01	32.15
April	2.63	7.2	1.21	46.95
May	4.47	12.3	1.02	58.58
June	4.58	12.6	1.35	68.35
July	3.15	8.6	1.15	72.17
August	2.79	7.6	1.46	69.64
September	3.36	9.2	1.31	61.73
October	2.76	7.5	0.90	50.34
November	2.97	8.2	0.88	37.03
December	2.70	7.3	1.12	28.19
For the year	36.47	----------	4.03	47.9

a 1876 to 1896.

The data in the above table accord well with the observed character of the stream, which is usually about as follows: A spring freshet in March or April is followed by medium water until June. High water often occurs for a few days after heavy rains in June, and sometimes also in August. Low water in later July, August, and September is accompanied by a depletion of stored ground water. Gradual increase in the flow occurs until the ground becomes frozen. Winter flow is

uniform and moderate, unless the stream is swelled by sudden melting of snowfalls. This frequently occurs in January or February, and is followed by moderate high water until the spring thaws.

In so far as the meteorological records at the different stations within the watershed are contemporaneous, they show a tendency for like variations from the mean rainfall and temperature at all stations during the same year. The region may therefore be considered fairly isoclimatic, since changes affecting any large portion of the watershed will in general similarly affect the whole region.

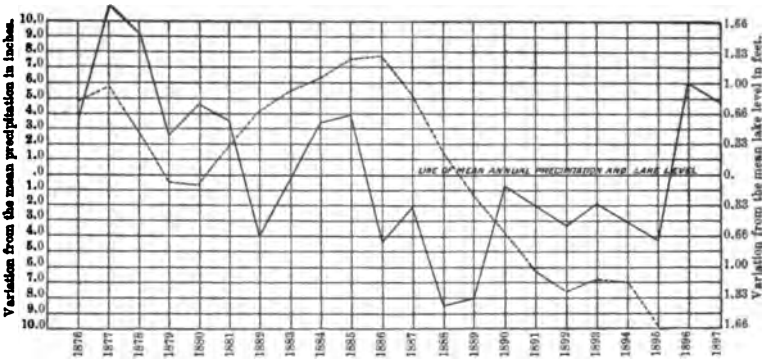


FIG. 1.—Fluctuations in the level of Lake Michigan and the annual precipitation at Kalamazoo, Michigan. (Prepared by R. E. Horton.)

The yearly rainfall record at Kalamazoo is shown by the solid line in the accompanying diagram (fig. 1). It will be seen that the yearly fluctuations from the mean annual rainfall are periodic in their occurrence. The ordinary cycle consists of a primary minimum followed by a period of increase for one to three years, and terminates in a primary maximum followed by a period of decrease for four or five years. This latter has a secondary superimposed cycle with its minimum and maximum usually one year apart. The times of recurrence of the different phases of the cycles thus far observed are shown in the following table:

Periodic rainfall at Kalamazoo.

Phase.	1	2	3	4
Primary minimum	----------	1882	1888	1895
Primary maximum	1877	1885	1890	1896
Secondary minimum	1879	1886	1892	----------
Secondary maximum	1888	1887	1893	----------
Whole period, years	6 or 7	6	7	----------

A fifth minimum may be expected about 1901.

Rainfall records at other stations within the watershed do not cover a sufficient number of years to determine whether there is a similar

periodicity in the rainfall throughout the watershed, nor are there gaging data at hand to show whether a corresponding periodic decadence takes place in the stream flow. If such should prove to be the case, the fact should be of commercial value to farmers and water-power users. The existence of a short rainfall cycle following such a regular periodic law is worthy of remark. Periodic fluctuations in rainfall having cycles of greater length than the above have been observed at various places in this country and abroad. At Sacramento, California, a forty-year rainfall record exists showing a six or seven year cycle as at Kalamazoo.[1] Many long records show no regularly recurring cycles, but in all cases which the writer has observed two or more successive dry or wet years occur with much greater frequency than would be the case if the sequence of wet or dry years were purely a matter of mathematical calculation. As a safe conclusion it may be said that certain meteorological conditions underlying rainfall tend to recur in more or less obscure cycles. It seems not improbable that the causes of such cycles are general in their application; and their apparent effects in many instances are masked by local or secondary conditions. The final solution of the problem will have an important bearing on questions relating to the water resources of any region.

RELATION OF LAKE LEVEL TO RAINFALL.

Observations of the height of the water surface of Lake Michigan have been made since 1800. In the absence of longer rainfall records within the watershed any relation that may be found to exist between the rainfall and the lake levels will be helpful in studying the run-off. The different kinds of fluctuations to which the water level of the lake surface is subject may be classified in relation to the causes producing them, as follows:

(1) Small tides, which at Chicago the United States Lake Survey found to have an amplitude of 1½ inches for neap tide to 3 inches for spring tide.

(2) "Seiches," so called, similar to those observed on Swiss lakes, and not thus far satisfactorily explained. They consist of small waves or pulsations having an interval of about ten minutes from impulse to impulse and apparently recurring without cessation.

(3) Temporary fluctuations, due to the wind. Colonel Whittlesey states that on August 18, 1848, a gale from the northeast reduced the water level at Buffalo 15½ feet lower than on October 18, 1894, the time of a terrible gale from the southwest.

(4) Annual variations, caused chiefly by differences of temperature and evaporation and by the melting of snow and ice. On Lake Michigan low water usually occurs in November and March. The highest water occurs in June and July.

[1] See climate, soil, characteristics and irrigation methods in California, by Charles W. Irish: Yearbook U. S. Dept. Agric., 1895.

(5) Secular variations, covering periods of several years, dependent on rainfall and meteorological conditions. The length of the periods is irregular and the times of recurrence of maximum and minimum phases can not be predicted closely. Knowing the mean annual levels for a series of years we may expect a similar series in the future, but with the times of the different phases very different. The number of maxima and minima within a given interval of years will, however, be nearly uniform for long series.[1]

On the accompanying diagram (fig. 1) the height, in feet, of the water surface of Lake Michigan, above or below the mean level (viz, 581 feet above tide) is shown, by a broken line, for a period of twenty-one years, 1876 to 1896, inclusive. It will be noticed that the lake levels are subject to a much greater relative fluctuation than is the rainfall. The two curves follow each other somewhat closely, although the periods are longer and more continuous for the lake levels. The year 1896 is exceptional in that it shows the lowest lake level recorded, while it was the year having the highest recorded rainfall at all stations within the watershed except Kalamazoo, where it was third in rank for twenty-one years. There is reason to believe that the level of Lake Michigan and the rainfall and the run-off of the watershed are covariants. Exceptional years can be ascribed to high summer temperature, producing luxuriant vegetation and excessive evaporation, so that little rainfall appears as run-off, or else the distribution of the rainfall through the year may be unfavorable to its reaching the streams and lake as run-off. The former was apparently the case in 1896. Careful inquiry from power users showed that within the Kalamazoo watershed there was a much greater shortage of water in the river in 1896 than in 1897, a year of considerably lower rainfall and mean temperature during the summer months. The mean rainfall at six stations in the watershed in 1896 was 41.9 inches, or 8 inches above the average.

RUN-OFF, RAINFALL, AND WATER POWER.

In studying stream flow it should be borne in mind that the amount of rainfall appearing as run-off in a given year is the resultant of a large number of more or less independent influences. Conditions may so combine that those factors which would ordinarily be in the background will in some instances become the controlling elements. Few, if any, rules without exceptions can be laid down, and each stream must be studied separately in all its relations.

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[1] The following references have been consulted in relation to lake levels:

(*a*) Chart of Fluctuations in the Level of the Great Lakes, by Charles Crosman, Milwaukee, Wisconsin.

(*b*) Climate of the Lake region, by Bela Hubbard: Pop. Sci. Monthly, January, 1888.

(*c*) Water-supply of western division of Erie Canal, by George W. Rafter: Report State Engineer and Surveyor of New York, 1896.

(*d*) Report United States Deep Waterways Commission: Washington, 1896.

(*e*) Reports of Chief of Engineers, U. S. Army.

The following table shows the discharge of the Kalamazoo watershed corresponding to different percentages of the mean annual rainfall appearing as run-off in the stream:

Relation between run-off and discharge of Kalamazoo River.

Proportion of mean annual rainfall appearing as run-off.	Depth of run-off on entire watershed.	Mean discharge of the stream.
Per cent.	*Inches.*	*Second-feet.*
110	37.26	4,803.2
100	33.87	4,366.5
90	30.48	3,929.8
80	27.09	3,493.1
70	23.7	3,056.5
60	20.31	2,619.9
50	16.92	2,183.3
40	13.53	1,646.7

The discharge of the Kalamazoo River was measured at a number of points along the stream during the spring high water of March, 1898.

Discharge of the Kalamazoo River at the Marengo dam, March 23, 1898.

Flow over dam and wasteweir	second-feet	456.8
Diverted for power purposes	do	113.
Total discharge	do	569.8
Drainage area above dam	square miles	261.
Discharge per square mile	second-feet	2.18

The depth of water flowing over the crest of the dam on March 23 was 15 inches. The height for maximum flow, which occurred on March 22 and lasted only a few hours, was 24 inches. This would have corresponded to a total discharge of about 930 cubic feet per second, or 3.5 cubic feet per second per square mile of drainage. We may compare this flow with that of Boardman River at Traverse City, a stream having a drainage area of 295 square miles. The river was measured on April 10, 1897, by Mr. George W. Rafter, and was at that time carrying about 300 cubic feet per second, or slightly over 1 cubic foot per second per square mile. Mr. Rafter shows that the flow of Boardman River undoubtedly may be as low as 100 cubic feet per second for two successive months, and that it may not yield more than 75 cubic feet per second, or about one-fourth of a cubic foot per second per square mile, for a period of a few days.[1]

[1] Water Supply of Traverse City, Michigan, by George W. Rafter and F. H. Northrup, city engineer, 1897.

Discharge of Rice Creek at Marshall, Michigan, March 23, 1898, 1 mile above point of confluence with Kalamazoo River.

Discharge over dam	second-feet	25.
Diverted for water power	do	125.
Tributary drainage	square miles	99.
Discharge per square mile	second-feet	1.5

Discharge of Battle Creek at Battle Creek, Michigan, March 24, 1898.

Discharge over dam	second-feet	253.3
Diverted for water power	do	75.4
Total discharge	do	328.7
Tributary drainage	square miles	180.
Discharge per square mile	second-feet	1.8

The discharge a day or two previous was somewhat greater, although at that time there was an extensive flood on the flats between the point of measurement and the confluence of Battle Creek with Kalamazoo River.

Discharge of Kalamazoo River at Battle Creek dam March 24, 1898.

Discharge over dam	second-feet	648.6
Diverted for water power	do	459.3
Total discharge	do	1,107.9
Tributary drainage area	square miles	510.1
Discharge per square mile	second-feet	2.17

Combining the two preceding measurements we get 1,436.6 cubic feet per second for the discharge of Battle Creek and Kalamazoo River at Battle Creek. This, with a total tributary drainage area of 690.1 square miles, gives 2.08 cubic feet per second as the discharge per square mile of drainage area.

Discharge of Kalamazoo River at Otsego, March 26, 1898.

Discharge over dam	second-feet	234.8
Diverted for water power	do	1,669.1
Total discharge	do	1,903.9
Tributary drainage area	square miles	1,600.0
Discharge per square mile	second-feet	1.2

For purposes of comparison a measurement of Grand River was made at the North Lansing dam.

Discharge of Grand River at North Lansing dam April 9, 1898.[1]

Discharge over dam	second-feet	642.
Diverted for water-power purposes	do	560.
Total discharge	do	1,202.
Approximate tributary drainage area	square miles	1,168.
Discharge per square mile	second-feet	1.02

This was at a time of medium water when the depth of water on the crest of the dam was but 14½ inches. At the time of maximum high

[1] Probably too small, owing to impossibility of getting precise data regarding capacity of all water wheels in use.

water in later March the depth of water on the crest of the dam was shown by the water marks to have been 29 inches. This would correspond to a total discharge of about 2,365 cubic feet per second, or 2.0 cubic feet per second per square mile of drainage area.

The preceding measurements, made at different points along the stream at nearly the same time, show about the flow that may be expected in Kalamazoo River at ordinary high water. The flow per square mile apparently gradually decreases as the tributary area increases. The low flow of Battle Creek may be due to a large proportionate area of lake storage, gathering the flood waters to be yielded as run-off at a later period.

The high-water flow exhibited by the gagings was preceded by heavy rainfalls and high temperature, as shown at several stations, within the watershed, in the accompanying table:

Meteorological conditions at stations on Kalamazoo River, March, 1898.

Station.	Precipitation.						Temperature.		
	March 10 to 13.	March 18 to 21.	March 24 to 28.	Total for month.	Greatest rainfall in 24 hours.	Day of heaviest rainfall.	Maximum daily.	Minimum daily.	Mean daily.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*		°*F.*	°*F.*	°*F.*
Olivet	3.38	1.61	0.48	6.16	2.02	10	67	10	38.8
Hanover	1.07	.55	1.10	3.57	1.	28	70	1	38.2
North Marshall	.91	1.94	.78	3.83	1.44	20	69	1	36.5
Battle Creek	1.35	1.50	.....	4.21	1.50	18	69	10	38.9
Kalamazoo	1.01	.47	.51	2.32	.51	26	69	8	39.
Hastings	1.27	1.12	.52	3.21	.80	19	69	1	37.2

No snow fell during the month. On March 1 the ground was covered with about 9 inches of packed snow. This melted rapidly, and, as the ground was frozen, appeared almost entirely as run-off during the month.

Depth of snow on ground at stations on Kalamazoo River, March, 1898. (a)

Station.	Mar. 1.	Mar. 2.	Mar. 3.	Mar. 4.	Mar. 5.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Somerset	9.0	8.0	7.0	6.0	5.0
Olivet	11.0	10.0	8.0	7.0	6.0
Battle Creek	5.0	5.0	4.0	3.0	3.0
Kalamazoo	12.0	12.0	12.0	10.0	10.0
Hastings	8.0	8.0	7.0	6.0	5.0
Average depth	9.0	8.6	7.6	6.4	5.6
Average daily melting	.....	0.4	1.0	1.2	0.8

Station.	Mar. 6.	Mar. 7.	Mar. 8.	Mar. 9.	Mar. 10.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Somerset	4.0	3.0	1.0	.....	.....
Olivet	5.0	4.0	3.0	1.0	0.0
Battle Creek	0.5	0.0	.....	.....	.....
Kalamazoo	8.0	0.5	None	.....	.....
Hastings	4.0	2.5	1.0	Trace	.....
Average depth	4.3	2.0	0.8	.....	.....
Average daily melting	1.3	2.3	1.2	.....	.....

a At sunset of each day.

There are no precise data at hand relative to the low-water flow of the river. By careful inquiry from power users it was found that in nearly all cases a shortage of water occurs for from two to six weeks in the months of July, August, and September. At such times the flow is insufficient to supply the water wheels now in use to their full capacity, and is less than the amount of water shown as being diverted for power purposes at the time the measurements were made. This would be expected from the rainfall records. The following table shows the lowest recorded yearly rainfall at stations in the watershed. As the minimum observed rainfall at a station decreases as the length of the record is extended, years may be expected to occur in which the rainfall will not exceed that at Kalamazoo in 1894, or 71.5 per cent of the mean, as shown in the table. This would be 25.43 inches for the entire watershed, using our previously derived mean of 33.87 inches. For the years 1888 and 1889 the total rainfall at Kalamazoo was but 56.53 inches. The rainfall for August frequently falls below 0.1 inch, and in 1889 the combined rainfall for July, August, and September was but 3.89 inches. If the flow from full ground water were 2 inches a month it would undoubtedly have been depleted in such a drought so as not to exceed three-fourths of an inch in a month. As little or no rainfall reached the stream directly, the

run-off in the summer of 1889 must have fallen as low at least as 0.7 cubic foot per second per square mile.

Years of least recorded rainfall at stations on Kalamazoo River.

Station.	Number of years' record.	Year of least rainfall.	Rainfall in lowest years.	Per cent of mean annual rainfall at station.
			Inches.	
Pulaski	4	1889	24.20	85.0
Concord	5	1888	24.17	81.8
Allegan	7	1895	26.95	75.8
Battle Creek	8	1879	20.20	74.8
North Marshall	8	1894	22.73	75.0
Hanover	9	1888	25.30	76.9
Marshall	11	1889	28.1	78.7
Kalamazoo	21	1894	26.07	71.5

HIGH WATER AT KALAMAZOO.

The extent and duration of high water at Kalamazoo is shown by the following data relative to the height of the river surface during floods at that place. At the township line, 2 miles below the city of Kalamazoo, the elevation of the bottom of the river bed is the same as at the Gull street bridge within the city, there being practically no fall in the river in that distance. As a result, the current is extremely sluggish, and a portion of the city is subject to frequent floods. The muck-covered river flats within the city are extensively devoted to the cultivation of celery. The annual spring flood is productive of little damage, but when floods occur during the summer months they result in a heavy loss to the celery growers and also tend to produce a bad sanitary condition, lasting for some time.

The following table gives the elevation of the river surface in feet above the city datum plane. The elevation of the water surface at its mean stage is 67 feet. The measurements at East avenue bridge are at the point of confluence of Portage Creek with Kalamazoo River. Those at Gull street bridge are below that point.

Observations of high water at Kalamazoo.(a)

Year.	Date.	Elevation.	Place of measurement.
		Feet.	
1883	June 28, 5 p. m	71.66	At East avenue bridge.
	June 29, 7.30 a. m	72.25	
	June 29, 1 p. m	72.42	
	June 29, 6 p. m	72.50	
	June 30, 7 a. m	72.74	
	June 30, 1 p. m	72.90	
	June 30, 6.30 p. m	73.08	
	July 1, 9 a. m	73.36	
	July 1, 6 p. m	73.59	
	July 2, 7 a. m	73.71	
	July 2, 1 p. m	73.71	
	July 2, 6 p. m	73.63	
	July 3, 7 a. m	73.40	
	July 18	67.88	
	August 17	68.55	
1887	February	*b* 74.77	
1888	July	67.55	Do.
1896	July 16	69.10	At Gull street bridge.
	July 19	68.74	
	July 31	70.69	
	August 1	70.99	
	August 3	70.49	
	August 5	69.20	
	August 8	68.99	
	August 19	69.50	
1897	March 12, 1.20 p. m	71.34	At East avenue bridge.
	March 12, 6 p. m	71.48	
	March 13, 7 a. m	71.84	
	March 13, 1.20 p. m	72.01	
	March 13, 6 p. m	72.34	
	March 14, 4 p. m	72.04	
	March 15, 7 a. m	71.54	
1898	March 14	71.35	At East avenue bridge during spring flood.
	March 15	71.80	

a These data were obtained from records furnished by Myron C. Taft, city engineer of Kalamazoo. Data for 1883 are not strictly comparable with those since that year, as an old dam has been removed and a shorter channel cut, allowing flood waters to pass off more quickly.

b Highest water recorded.

WATER POWER.

The fall and slope of the river is shown by the accompanying table. In comparison with this the next table (on page 38) shows the number of feet of fall used for water power at dams on the main river. Out of a total fall of 338 feet from Albion to Saugatuck, 76 feet is now used for the production of power. The aggregate rated power of the water wheels in use on the main river is between 4,000 and 5,000 horsepower. This includes 18 flouring and 5 paper mills, besides planing mills, machine shops, municipal waterworks, etc. There are also 20 dams on tributaries with a developed water power, so far as it could be ascertained, of 1,500 horsepower.

Fall and slope of Kalamazoo River.[1]

Portion of river.	Distance along river.	Total fall.	Mean slope per mile.
	Miles.	*Feet.*	*Feet.*
Albion to Marshall	12.25	52	4.22
Marshall to Battle Creek	13.25	70	5.26
Battle Creek to Kalamazoo	23.37	43	1.84
Kalamazoo to Allegan	19.78	57	3.00
Allegan to Saugatuck	32.50	116	3.55
Albion to Saugatuck	101.10	338	3.34

As has been shown, the capacity of water wheels now in use is fully as great as the flow of the stream will warrant without the construction of new dams. Viewed from an economic standpoint the water power of the stream can not be greatly increased over the present development unless some method of flow regulation and conservation of the flood waters be put in operation.

[1] The fall has been deduced from railroad profiles. See topography and climate of Lower Michigan, Report Michigan State Board of Health, 1878.

Water power developed on Kalamazoo River.

Location of dam.	Head or fall.	Net horse-power developed.
	Feet.	
North Branch at Horton	10	55
North Branch at Concord	9	118
North Branch at Bath Mills	8	33
South Branch at Mosherville	14	80
South Branch at Homer	8	214
South Branch at North Homer	7	69
Main River at Albion	13	298
Main River at Marengo	7	118
Main River at Marshall	6	.....
Main River at Ceresco	8	289
Main River at Battle Creek	12	469
Main River at Plainwell	19	786
Main River at Otsego	12	1,725
Main River at Allegan	8	.....

WATER POWER OF HURON RIVER.[1]

Huron River rises in the town of Clarkston, Oakland County, Michigan, and runs southwest into Livingston County, draining many lakes in Oakland County. The chief of these are White, Union, Upper Straits, Lower Straits, Pine, and Spring lakes, averaging one-half to 1 square mile in area. In the southeast part of Livingston County it takes the waters of four lakes, viz, First Base Lake, Second Base Lake, Strawberry Lake, and Portage Lake, varying from 1 to 2 square miles in area. Portage Lake is the largest and also the lowest down the valley. It is 3 or 4 miles long and averages about half a mile in width. It is fed by Portage River, which itself drains ten lakes of small size. From there the Huron flows northeast, then southeast again, and enters Lake Erie just below the mouth of Detroit River. The total drainage area is 950 square miles.

The country is flat or rolling, with a glacial drift of clay, sand, and gravel, well adapted to the raising of wheat, which is the staple and which gives work to many flouring mills. The river was declared navigable by Congress. Once a flatboat for freighting ran from Ypsilanti 30 miles to the mouth, but its use was discontinued on the advent of railroads. There was too little water for navigation, and the dams interfered. Boats run up to Rockwood, 4 or 5 miles up, on the line of the Lake Shore and Michigan Southern Railroad.

No lumbering is done, and the stream is devoted to manufacturing,

[1] From the report by James L. Greenleaf, special agent of the Tenth Census of the United States, Vol. XVI, p. 496 et seq.

for which it is peculiarly suited. It has a fall averaging 5 feet a mile, and this near its mouth. It is on the line of several railroads, and, owing to adjacent lakes, the storage capacity is large and its flow more regular than that of various other rivers in the country. The banks of the river are usually from 9 to 12 feet high, and hence ponds do not spread. The bed and banks are usually hard clay, or a sort of conglomerate of clay, gravel, and stone (till). There is no rock bed except at Flat Rock, the first fall above the mouth.

The course is extremely winding. The Michigan Central Railroad runs along the river 17 miles from Ypsilanti to Dexter, and in that distance crosses it sixteen times. The bulk of the manufacturing is between Dexter and Ypsilanti, on the line of the Michigan Central Railroad.

At Ypsilanti the average breadth is 100 feet, the average depth 1½ feet, and the maximum depth about 5 feet. The ordinary low-water flow, calculated from the estimated horsepower, is 220 cubic feet per second, or 0.23 cubic foot per second per square mile of drainage area. The available power under 10 feet head at ordinary low water is from 225 to 250 horsepower. There is no difficulty from floating ice. A mill using the full average power of the stream can run at full capacity ten months of the year, and during August and September at half capacity. The river has no large tributaries below the lakes, and hence the power for a given fall is nearly the same in the upper and in the lower part.

DEVELOPED POWER.

Most of the mills are between Dexter and Ypsilanti, a distance of 17 miles. Above Dexter and below Portage Lake are the Hudson and the Dover mills. Below Ypsilanti are mills at Rawsonville, Belleville, etc.

Three forms of dam are in use: (1) The pile dam, a common form. A typical specimen is one belonging to the Ypsilanti Paper Company. Piles were driven 6 feet between centers, both across and down the stream, covering a strip 50 feet wide across the channel. The ends were then cut, so that taken together their surface formed two planes, meeting at the center line of the dam, like a roof. The space between the piles was filled in with stone and the top planked over. A plank apron was built on the lower side. (2) The crib-work dam—ordinary timber cribs, filled with stone and planked over. (3) The frame dam, used at the Dover mills. A triangular frame was built and planked over and stone thrown under; a plank apron was built on the lower side, and gravel thrown in on the upper side. So far as ascertained, there have been no instances of the breaking away of dams.

At Flat Rock, 7 or 8 miles above the mouth of the river, is the first power. There is about 100 horsepower available.

At New Boston and at Belleville powers are being developed. There are two flouring mills at Belleville. The banks are high and well adapted to ponding.

At Rawsonville is a flouring mill with 7 feet head. There is 150 to 175 horsepower available.

Ypsilanti is the chief manufacturing center on the river. There are three paper mills, two flouring mills, a woolen mill, and a small custom sawmill, also a low dam in connection with the city waterworks. The banks are from 9 to 12 feet high, and ponds do not spread. There are three dams, about one-half to three-fourths of a mile apart, and no fall is wasted. The bed is hard clay. The Michigan Central Railroad runs up the valley from this point, and freight facilities are good.

The lower pond has 7 feet available fall and 175 available horsepower. There is a pile dam 190 feet long. The average breadth of the pond is about 150 feet and the length half a mile. The power is utilized by the Ypsilanti Paper Company's mill. The middle pond has 5 feet available head and 125 available horsepower. The only mill at the power is the Huron flouring mill, which uses on the average 75 horsepower. There is a pile dam 5 to 6 feet high and 100 feet long. The pond is from 150 to 200 feet broad and half a mile long. The upper pond is owned by the City flouring mill and the woolen mill, and feeds them and also a small sawmill fed from the race of the flouring mill. The fall at the dam is 8 feet and the available power is 225 horsepower. The dam is from 120 to 130 feet long, the area of the pond 35 acres, and the depth 5 or 6 feet; the dam does not spread much. The woolen mill uses 42 horsepower. The flouring mill, situated on a race, has 1 foot additional fall, making the total fall 9 feet; it uses 100 horsepower. The sawmill, when running, uses about 10 horsepower.

The mills of the Peninsula Paper Company are situated at a pond a short distance above Ypsilanti, and have 300 available horsepower.

The largest power on the river is at Lowell, and it is used by the Ypsilanti Paper Company. The available head is 16 feet, and 400 horsepower is available. The pile dam has been described; its length is 166 feet. The area of the pond is 30 or 35 acres.

At Ann Arbor, 7 or 8 miles above Ypsilanti, there is a level with a head of 10 feet and 250 available horsepower. The dam is a pile dam 200 feet long, which is utilized by the Ypsilanti Paper Company's mill. Above it is another level with the same head and power. A woolen mill, a flouring mill, and a sawmill are fed from this pond, using altogether 100 horsepower. The dam is 140 feet long.

At Foster's station, 3 miles from Ann Arbor, there is a fall of 9 feet, all of which is utilized by a paper mill taking 100 horsepower and a woolen mill taking 58 horsepower. The power is estimated at 300 horsepower for six months of the year.

At Delhi there are two flouring mills, a woolen mill, and a sawmill, all using water from the same level. There is 7 feet head and 140 available horsepower. Usually all the mills can run at once. The

dam is of crib work, 150 feet long. The Scio flouring mills are above Delhi, and have 8 feet fall, with 140 available horsepower. The dam is of crib work, 100 feet long.

Dexter has a flouring mill, a woolen mill, and a sawmill, all run from the same level. The available head is 5 feet. The dam is of crib work, 75 feet long.

Above Dexter are the Hudson mills, with 5 feet head and 75 horsepower—a crib-work dam 100 feet long,—and the Dover mills, with 7 feet head and 100 horsepower—a frame dam 100 feet long. The ponds above Ann Arbor average from 120 to 180 feet wide and one-half mile to 2 miles long. There are no important powers above.

UNDEVELOPED POWER.

There are a few undeveloped powers. Three miles below Ypsilanti is one of 300 horsepower, which has not been used, because the pond would spread over valuable farming lands and because the location is not near the railroad. One mile below Ann Arbor is a power with 4 or 5 feet fall, unimproved, giving from 100 to 125 horsepower. It is on the line of the railroad. The small power, compared with the cost of improvement and lack of demand for it, is the apparent reason it has not been improved. One and one-half miles above Ann Arbor is a fall of 10 feet, unimproved. Nearly 300 horsepower is wasted. It was used formerly by a sawmill, now burned down. It is on the line of railroad and awaits improvement.

WATER POWER OF RAISIN RIVER.

The North Branch rises in Jackson County, and the South Branch in the northwestern corner of Ohio. They unite east of the center of Lenawee County and flow into Lake Erie. The drainage area is 1,162 square miles. Near the mouth it is 200 or 300 feet wide, but in ordinary water it is only from 6 to 12 inches deep, with a sluggish current. At Adrian it is a small stream, 25 or 30 feet wide, with a moderate current, about 1 foot deep. There are several small mills on the river, but no power of importance.

USES WHERE QUALITY IS IMPORTANT.

USE FOR DRINKING.

INORGANIC IMPURITIES.

The uses of water where the quantity required is not excessive and is usually readily obtained, but where the proper quality is important and is not so easily maintained, will now be considered. Impurities are of two kinds, organic and inorganic. Under the first head are classed sewage, swamp contaminations, ammonia, and bacteria. Salt, though inorganic, has often been considered an indication of the presence of organic contamination. But in the district under consideration it is not true, and a knowledge of the normal chlorine percentage of the

same class of water in the same neighborhood is a prerequisite to the application of the chlorine test as indicative of sewage. Investigation of this normal percentage has been undertaken for the State board of health by Prof. D. Fall. Salt is one of the commonest inorganic constituents, only less common than the acid carbonates of lime and magnesia, which are always present except in some sandstone wells and in cistern waters. Iron in some shape, and sulphates of lime, etc., are also not uncommon in wells.

The quantity of mineral matter in the lakes or rivers is not sufficient to affect the water appreciably as a supply for healthy people, while for cases of uric acid diathesis, where lime should be avoided, many sandstone wells and shallow surface wells in sand seem specially suited, since their water contains less than the usual amount of lime. Occasionally the water from deeper wells is softer. Filtered rain water is used and is not at all unpalatable when one is accustomed to it. Distilled water is also manufactured and sold.

More detailed conclusions as to the connection between the chemical character and the suitability of a water for drinking will be found in a subsequent paper.

Dr. W. H. Deadman, veterinary surgeon at Alpena, asserts that 80 per cent of all the horse disease in northern Michigan is due to hard water. The hardness of water varies in the lakes and rivers, and probably varies with the season of the year and with the depth at which the samples are taken.

Some of the shallower rock wells, almost all those over 500 feet, and a few of the wells in drift are so highly charged with mineral matter (over $\frac{1}{2}$ oz. per cubic foot) as to be cathartic or otherwise unpleasant and unfit for domestic use. It is important to note, however, that in many cases the mineral matter comes from beds of salt or gypsum, or from even less continuously porous beds, and that therefore fresh water may at times be obtained by proper casing, even under beds of salt. There are a number of cases on record in which fresh water has been obtained under salt. A notable case is that of Mr. Leipprandt, near Caseville (sec. 13, T. 17 N., R. 10 E.), who has a well 100 feet deep that is very salt, and another well 280 feet deep (cased to 228 feet) which yields good fresh water.

ORGANIC IMPURITIES.

Organic impurities are most prevalent when inorganic are least so, in the shallow wells, rivers, and ponds, and even in cisterns and standpipes. Yet even deep artesian wells are not by any means free from organic matter—for example, the Bad Axe supply. Such matter is, however, probably harmless. Organic impurities may be divided into two kinds—mere vegetable growths of algæ, etc., and the more dangerous bacteria of typhoid. The former are not wholesome, though not so dangerous as the latter, and may form in cisterns and standpipes in very pure water, as, for example, at Bad Axe and at Leaton,

and are especially abundant in artesian water. The exclusion of light tends to check their growth in cisterns. A few cases are reported where malaria was cured by a change to drinking artesian water, seeming to show that bad water, and not bad air, was the cause of the disease. But it is of course possible that it was not the previous presence of vegetable matter in the water that caused the disease, but rather the curative properties of some mineral ingredient in the artesian water that effected the cure. Wooden or plank casing, which is much too common, soon gives a foul taste to water, and any dug well with a basin is liable to have foreign matter get into it that does not improve its quality—angleworms, frogs, mice, moles, rats, and snakes, which well drillers find on cleaning the wells.

Wells dug or driven in sand only, without a clay capping, are liable to surface and sewage contamination, though of course when they are put down 100 or 200 feet the danger is greatly reduced by the sand filtration. Even then it would be well to have the point and strainer considerably below the top of the water line. It would save trouble in an exceptionally dry year, and would give additional protection.

The practice of having any dug or shallow surface water well in a barnyard or near a privy is uncivilized and is only the temporary expedient of uneducated immigrants who have recently arrived, and one is glad to see that among the intelligent and more prosperous farmers deep driven or drilled wells are becoming the rule and not the exception. Too commonly, however, the well water of the deep driven well is allowed to flow into the old dug basin, a practice which has many objections (considered on page 73). The casing should extend from the pump to the water-bearing stratum. The well should be removed from the barnyard, to which the water may be conducted by a long launder. If a surface or dug well is the best that is available, it should be out in the orchard, and removed from sources of contamination.

Digging is sometimes the best way of sinking through a bowldery formation. A good practice, prevalent in Emmet County, is to cement the wall as the well is sunk, using a 3-foot boiler tube as a shield. Mr. E. R. Phillips, of Bay City, uses such a cemented well in the city, but he has a depth of sand and charcoal at the bottom which acts as a huge filter—an excellent palliative expedient.

Rivers and lakes are the great sources of supply for village and city waterworks, being but rarely used by individual farmers, except as some dry season forces them to haul water. Unfortunately, as we have already remarked, too often an ample supply has been considered the prime requisite for city plants.

DAIRY USE.

One great advantage of flowing wells is in keeping milk cool. The temperature of such wells approaches the mean annual temperature of the place at which they are, plus a certain small amount,

dependent on the depth below the surface from which they draw their water, about 1 degree for 60 feet. The annual fluctuations of temperature hardly affect them, though in fact if from 30 to 60 feet deep they are colder in summer than in winter. This is not only to be expected theoretically, but has been verified in practice. Professor Davis found, in studying some of the Alma flowing wells, that the water of one about 55 feet deep stood at 52° F. in winter and at 48° F. in summer.

Since the mean annual temperature of Michigan, as is shown in fig. 4, varies between 39° F. and 49° F., the temperature of flowing wells or springs should have about the same range, and the recorded observations of the shallow flowing wells are but 4° or 5° higher. This is precisely the range of temperature best adapted to keep milk. Such flowing wells may be obtained all over the Saginaw Valley, and, as the map (Pl. VII) shows, such wells, drawing water either from the rock or from gravel beds under clay, occur throughout the State. These wells yield a water very favorable to the growth of algæ, and the vegetable matter must be frequently cleaned from the tanks. Darkness checks its growth.

For use in refrigeration or for general dairy use the same purity is not requisite as in drinking water. While of course water brought in contact with butter should be free from dangerous organic impurities, inorganic mineral constituents, like salt and sulphates, are reported to be some advantage and help in hardening the butter. Much of the water of the Saginaw Valley, which is rather too salt for domestic use, is excellent for dairy purposes.

COOKING, LAUNDRY, BOILERS.

Next to the use for drinking naturally comes cooking, laundry, and boiler use. As organic impurities are rendered harmless when boiled, this factor is eliminated, except when, as is occasionally the case, "foaming" is produced in the boiler. The deposit of mineral matter in the teakettle is usually either carbonate or sulphate of lime, magnesia, or iron. If the former, a little acid quickly removes it. Iron is betrayed by its color. Only occasionally is water found with so much mineral matter as to be unfit for cooking. In such cases iron is usually the offending element, turning tea black and discoloring potatoes. Water, if allowed to stand, will precipitate most of the iron. It forms a scum which is at times mistaken for oil.

Impurities of another class, i. e., hydrogen sulphide and other gases, as well as traces of oil, occur more or less in various parts of the State. Hydrogen sulphide occurs in various places, and is characteristically common just beneath the Devonian black shales. A moderate amount does not seem to be injurious, and users soon get used to its peculiar odor; but in the deeper salt wells in the southeastern part of the State it is disagreeable, in some cases seriously affecting the eyes.

Another important consideration in regard to water is its effect on

boilers. The impurities which deposit scale are the sulphates and carbonates of lime and magnesia, and many railroads have spent considerable money to obtain purer boiler water. Water with 8 to 10 grains of carbonate of lime to the gallon is considered hard, and when there are over 40 grains to the gallon—and there are large districts where this amount is present—the water has been condemned by railroad authorities. Mount Pleasant water is typical as a bad water for use in boilers.

The sulphate of lime is worse than the carbonate. The carbonates of lime, magnesia, and iron are somewhat precipitated by exposure to the air, and further by boiling or by the addition of quicklime. In every district it will be found that the water of certain wells is considered good for threshing machines, both in quantity and in quality.

In the steam plant of the University of Michigan, which furnishes steam heat and also drives a couple of engines, the condensed water is returned to the boilers. In addition, the engineer informs me that a supply of about 400 gallons plus about 10 per cent is used daily. This is nearly all derived from cisterns, representing about eleven months' supply. I obtained, through the kindness of Professor Cooley, a blue print showing the exact roofage used in supplying the cisterns. From this I estimate that 19,493 square feet of catchment area furnishes 17,600+ cubic feet of water. This is not far from 1 cubic foot per square foot of catchment surface, or 38 per cent of the Ann Arbor rainfall (32 inches). It is impossible to estimate the amount of leakage, as there are five cisterns, scattered at considerable intervals over the grounds, and part of the rainfall of exceptionally wet seasons may overflow the cisterns. It seems as though a larger percentage of the rainfall might be saved, although the percentage of run-off to rainfall is apparently higher than in the Kalamazoo Basin. Much of the winter snow will of course slide off, and in each rain a certain percentage must be allowed for wetting the roof and for evaporation. It will be safe, however, to estimate that 10 feet square of roof surface will yield 100 cubic feet, or about 25 barrels, of water per annum.

At the Agricultural College the custom is to heat the water to boiling and then allow it to aerate, cool, and settle. At the Midland Chemical Works they propose to remove the hardness first with lime and then with soda ash.

In any case it is well to get the water as pure as possible before introducing it into the boiler; and heating the feed water with the exhaust steam and allowing it to settle will certainly help. The growth of the soda-ash industry in Michigan will doubtless permit the economical use of that chemical.

Cistern or rain water and condensed boiler water are of course free from these impurities, and it might be well to plan an agricultural engine for use in the Saginaw Valley with a condenser arranged to use its water over again and again. The soda salts, common salt, and sulphate of soda are not objectionable, but rather help to clean out

scale, and in the Saginaw Valley are often present in the water. The chlorides of lime and magnesia and the heavily carbonated waters are corrosive.

Generally speaking, the softest waters are either rainfall waters from sands so near the surface that the lime has been leached out, or waters from wells in the Napoleon and certain other sandstones, which, even when salt, run much lower in sulphates than do the waters of the higher beds.

What has been said concerning cooking and boiler feed water applies also to that for laundry use. The prevailing hardness of the water has led to the extended use of cistern water for washing. If one-third the rainfall can be saved, a roof 10 feet square will yield about 600 gallons a year. It is only in part of the sandstone district that the wells are so soft that there is no object in saving rain water. To supplement rain water very shallow wells are sometimes used, when only 2 or 3 feet of sand is underlain by clay and has been washed free from lime, so that one can get practically surface rain water. In a fresh cut in a gravel bank (e. g., at Mecosta), the leaching out of the lime and iron from the first 2 feet or so is well marked by a dark line at the bottom where the lime and iron are concentrated, which have often cemented the pebbles together into one form of "hardpan," a term also applied to till.

The same remedies for hardness mentioned above, viz, exposure to air, boiling, and the addition of quicklime or sal soda, are also available in laundry use, and are known as "breaking" the water.

It is advisable to get the water as pure as possible before its injection into the boiler, rather than to rely entirely on "dosing" the boiler.

SUGAR-BEET INDUSTRY.

In the manufacture of beet sugar it is important to have a water as free as possible from salts, for every molecule of chlorine salt is said to invert about five molecules of sugar into glucose. Organic matter is said to work in like fashion. None of the surface waters, and but few of the deeper drift wells, are really disqualified, although there is considerable difference between them. Most of the deeper rock wells, however, over 300 feet in the rock, except those in the northern part of the State and, relatively speaking, the waters of the coal basin, would be unsuited for such use. A great deal depends on prompt handling and skill.

PHOTOGRAPHY AND OTHER USES.

For photography, paper making, wool scouring, and manufacturing industries generally it is important to have as little mineral matter as possible. For photography rain water can be used only if fairly free from organic matter. Photographers frequently use the common hard water. One possible exception to the general rule that sulphates

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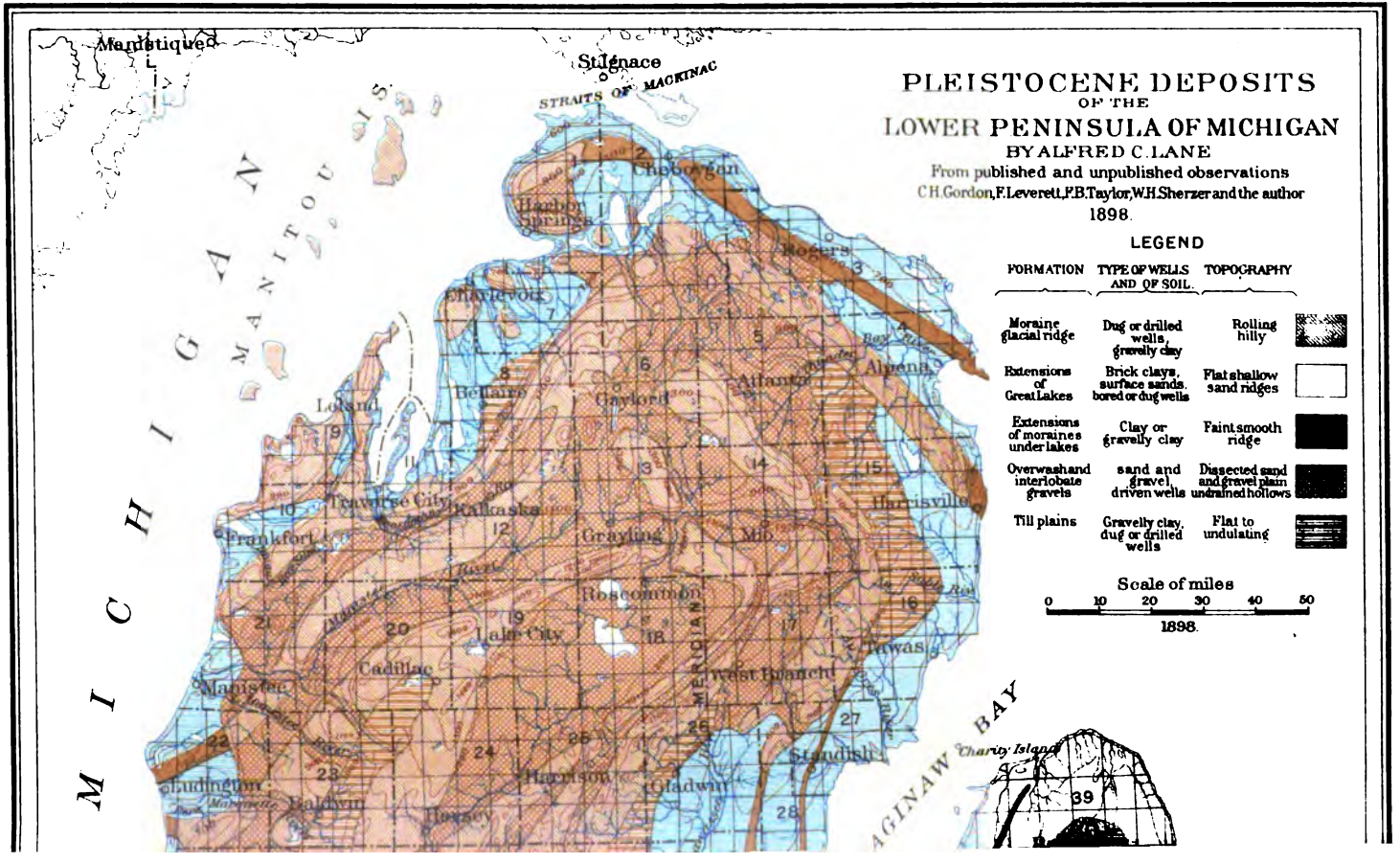
Manistique
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STRAITS OF MACKINAC
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Petoskey
Harbor Springs
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Bellaire
Gaylord
Atlanta
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Rogers
Lolsand
Traverse City
Kalkaska
Grayling
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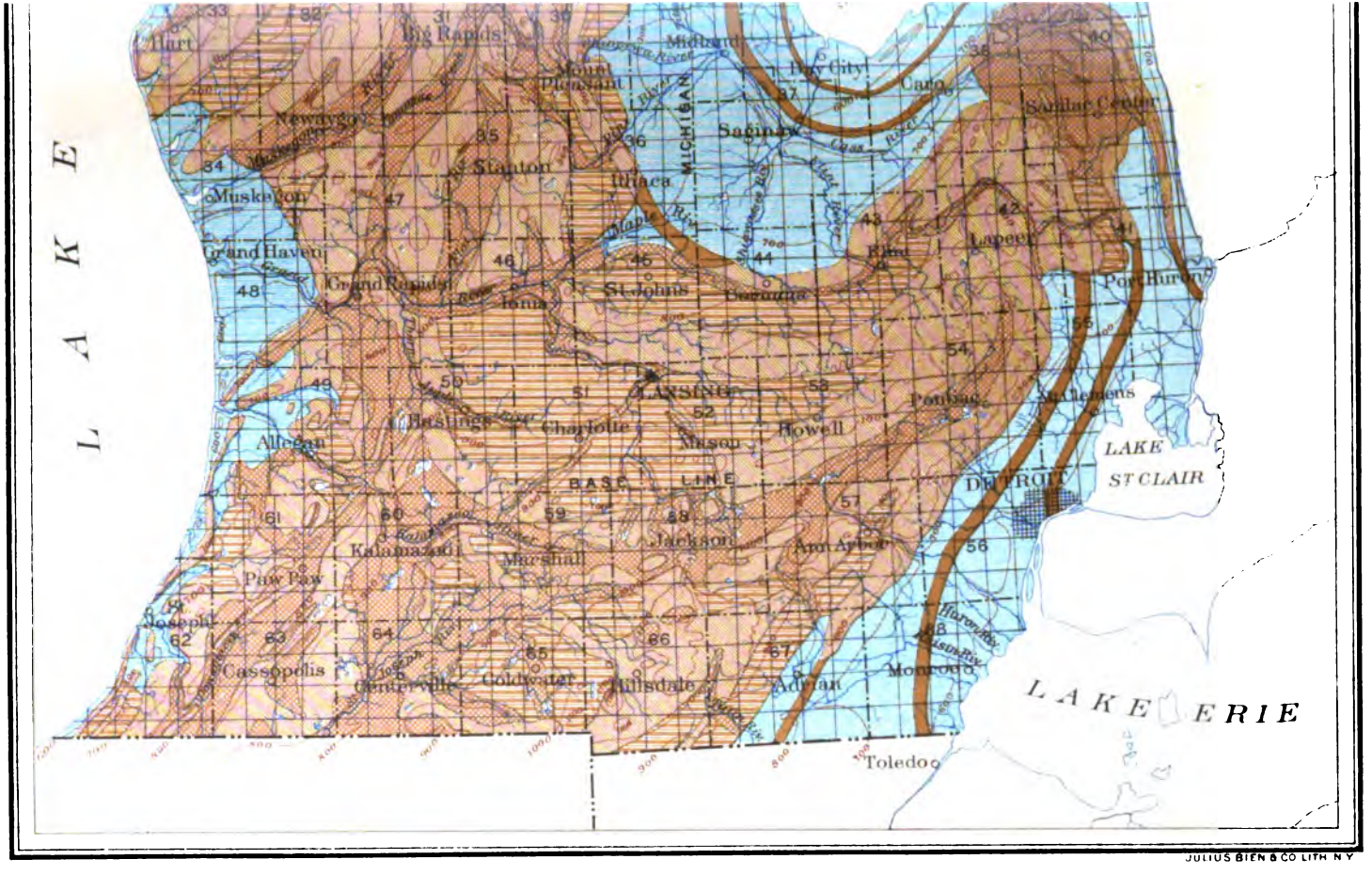
Harrisville
Frankfort
Roscommon
Lake City
Cadillac
Manistee
Tawas
West Branch
Standish
Ludington
Baldwin
Hesperia
Harrison
Gladwin
AGINAW BAY
Charity Island
MERIDIAN
PLEISTOCENE DEPOSITS
OF THE
LOWER PENINSULA OF MICHIGAN
BY ALFRED C. LANE
From published and unpublished observations
C. H. Gordon, F. Leverett, P. B. Taylor, W. H. Sherzer and the author
1898.
LEGEND
FORMATION
TYPE OF WELLS AND OF SOIL.
TOPOGRAPHY
Moraine glacial ridge
Dug or drilled wells, gravelly clay
Rolling hilly
Extensions of Great Lakes
Brick clays, surface sands, bored or dug wells
Flat shallow sand ridges
Extensions of moraines under lakes
Clay or gravelly clay
Faint smooth ridge
Overwash and interlobate gravels
sand and gravel, driven wells
Dissected sand and gravel plain undrained hollows
Till plains
Gravelly clay, dug or drilled wells
Flat to undulating
Scale of miles
0 10 20 30 40 50
1898.



JULIUS BIEN & CO LITH N.Y.

are deleterious in manufactures is ale, in which, it has been said,[1] a certain amount of calcium sulphate is an improvement. Generally speaking, however, the breweries take great pains to get as pure water as possible. In compounding medicines also a pure water is of importance. The industries (salt, potash, bromine, and mineral water) dependent on minerals in the water are not here treated.

The industries requiring pure water are well worth consideration in reenforcing the demand for pure water and in estimating the availability of several possible supplies. Of course pure water is important to those seeking the most favorable location for such industries.

QUALITY AND QUANTITY COMPARED.

It may be said in general that while for uses which look first to quantity the lakes and rivers are the natural source, for freedom from organic impurity the deeper wells have the preference. Water from both these sources, except from some sandstone and coal measure wells, is rather hard, so that for washing cistern water is preferred. The deeper the well the greater the inorganic impurity, with some noticeable exceptions, chiefly in that the waters from the Napoleon sandstone and the Dundee limestone, down to the Sylvania sandstone, may be less charged than the waters from beds above.

The Great Lakes, with properly located and guarded intake pipes, furnish a good city water supply. The supply from all rivers, even the Detroit and St. Clair, should be filtered. Many towns fortunately possess an ample supply from deep wells. Only in that territory which lies at the same time in the region of the old lake bottoms, colored blue on the map (Pl. II), and that of the Coldwater shales (see Pl. VI) is the outlook for deep-well supply entirely unpromising, so that carefully filtered river water or aqueducts from springs near the flank of the nearest moraine seem the most hopeful sources of large supply for towns.

Statistics show that city use is generally extravagant, rarely less than 100 and rising to 200 and 300 gallons per capita a day. This is much more than domestic use requires, and is due partly to uses where quality is comparatively no object, such as street sprinkling and fire protection, the use of lawn hose and of water for elevators and light machinery, etc., but largely to sheer waste. It is not for the public welfare to stint the use of water to the detriment of cleanliness, but it is advisable to stop waste, and the effect of meters in this respect is wonderful. It would be well to have a minimum price for a certain quantity, say 30 gallons a day for each room served, to prevent undue economy, and after that charge in proportion to the amount of water used. It is a question, also, whether the more wealthy residents who use the lawn sprinklers freely pay more or less than their fair share of the water rates at the present schedules.

[1] See Ency. Brit., article Burton.

Some few towns, like Rochester, possess an ample supply of unexceptionable water, though even in such cases a prudent provision for the interests of posterity would guard against the waste which has already lowered the head in some communities to a dangerous extent. A flowing well is valuable, and the head needful to produce one should not be recklessly wasted.

Most of the smaller towns, however, stand on a border line. They can get a supply of well water which will suffice for ordinary and economical use but not for emergencies. This is a field for reservoirs and for filters. It should be remembered that the efficacy of a filter depends very largely on its not being used constantly, but allowed, as it were, to rest from time to time. Filtration of a lower grade supply is especially adapted for extraordinary demands. The ordinary supply of such towns as Alma and Mount Pleasant should be from deep wells, but in case of fire filtered river water might be turned in. To use unfiltered river water without notice to consumers ought to be out of the question. Accustomed as people may be to the better supply they will not use the same precautions as if they had the poor supply regularly. In the Manual of American Waterworks it appears that there are many towns which, in case of fire, pump directly from the river.

Lower Michigan is so situated with respect to the Great Lakes that most of the larger towns can derive from them a satisfactory supply by using proper precautions. Many others can derive a domestic supply from the Marshall sandstone. Only along the Saginaw River is the question of water supply at all serious. Saginaw Bay is exceedingly shoal, and for East and West Saginaw and Bay City the supply can not be regarded as at all satisfactory.

It seems, however, that there is destined to be a city of the first rank along Saginaw River. Even if from the sandstones (not merely the drift which has been tested unsuccessfully by the waterworks experimental wells) a sufficient supply of water relatively free from mineral can not be obtained,[1] it seems certain that to the west and southwest, in Tuscola County, less than 25 miles away, the water resources can be utilized for a metropolitan water supply.

CLIMATE.

The most detailed account of the climate of the State is by the former State geologist, A. Winchell.[2]

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[1] The recent explorations for coal and city wells show that here and there in channels there are within the first 200 feet beneath Saginaw areas of water-bearing sandstones.

[2] Tackabury's Atlas of the State of Michigan, edited by H. F. Walling. First edition, 1873; second edition, 1884.

Proc. Am. Assoc. Adv. Sci. (Troy meeting), August, 1870.

Harper's Magazine, Vol. XLIII, July, 1871, p. 275.

Wegweiser der Michigan, Hamburg.

Oesterreich. Ges. für Meteorologie, Wien. Zeitsch., Bd. VIII, February 1, 1873, p. 40.

From Winchell's work much of the material in this chapter is abstracted. It is, of course, not wholly up to date, but Prof. E. A. Strong, of Ypsilanti, director of the State weather service, who has studied and compiled the later data, informs me that they are substantially correct, and I am indebted to Mr. C. F. Schneider, director of the State weather service, for additional figures.

The most notable features of the climate of the Lower Peninsula may be summed up in a few words by saying that it is what its name implies, pene-insular, modified by the fact that it has greater relief than the neighboring States to the west. The mean temperature for the year is higher on the east shore of Lake Michigan than on the west shore, as is also vividly shown by Winchell's isothermals of the extreme minima, and in this respect, owing to air drainage, the highlands have an advantage over the lowlands, the central part of Michigan being better off than St. Louis, so far as the extreme cold of winter is concerned. In fact, the mean of January temperature is higher and of July heat lower than farther west.

It is obvious that these facts have a bearing on the run-off of the streams. The amount and distribution of the rain or snow must also be taken into consideration. This has been carefully studied for the Kalamazoo River by Mr. Horton in a previous section, page 26. The average precipitation for the Lower Peninsula is some 32 inches. The heavy dews which occur in some parts of the State need not be taken into consideration as run-off, however important they may be for the farmer, because they are largely evaporated or absorbed by plants and do not become a part of the water resources. Some idea of this factor might be obtained from the relative humidity of the air, but as to actual rainfall the Lower Peninsula is in about the condition of Wisconsin. The distribution of this precipitation is also of interest. The contrast in the winter between the upper and lower parts of Michigan has frequently been observed. The region of Lake Superior will be buried in snow 2 or 3 feet deep when through the lower part snow is found only in scattered patches. Winchell gives the following table:

Distribution of precipitation in Michigan by seasons.

Season.	Upper Peninsula.	Lower Peninsula.	The State.
	Per cent.	*Per cent.*	*Per cent.*
Spring	19.	25.8	23.8
Summer	27.	28.7	28.3
Autumn	28.8	27.3	27.7
Winter	22.	19.1	20.
Total	96.8	100.9	99.8

Taking into consideration both the milder climate and the marked diminution of precipitation in winter, the table above indicates less accumulation of snow during the winter. Thus the spring freshets are much less decided than in many other States, while the temporary winter snows largely sink into the ground. From this results a steadier flow and less erosion and fewer flood plains in the streams than would otherwise be the case. The many lakes without outlets would fluctuate

even more violently were this not the case, and doubtless be more likely to cut channels for themselves. The abundance of lakes also helps to keep more uniform the flow of the streams. The effect of cultivation, on the other hand, is to make the spring freshet sharper and earlier, for the snow disappears first from plowed fields and cleared lands.

For the four figures (figs. 2 to 5) illustrating Michigan climatology I am indebted to the director of the Michigan weather service, Mr. C. F.

FIG. 2.—Distribution of average minimum temperature in Michigan.

Schneider. They are compiled from the records of the various stations (about 108 in all), and are the result of averaging all the data on file in the office, in general covering a period of about ten years, except for the precipitation chart (fig. 5), which covers a much longer period. The period of observation is not the same for all stations. The temperature observations at Lansing go back to 1873.

Fig. 2 shows the average of the average diurnal minimum temperature for each year.

The mollifying effect of the westerly winds blowing off Lake Michigan and Saginaw Bay is very apparent. The highlands northwest of Saginaw Bay have extremely low minima, as might be expected, while those southeast, on the contrary, have not so low minima as the Saginaw Valley, and it appears that the valleys draining thither have, on the whole, lower minima than those draining southeast.

FIG. 3.—Distribution of average maximum temperature in Michigan.

Fig. 3 similarly gives the average of the average maximum temperature during each year. At the northern end of Lake Michigan the maximum as well as the minimum temperature is raised, and the general average is abnormally high (fig. 4). At the lower end, however, the maximum and the mean temperatures are but little raised, so that the lake serves only to mollify the frosts of this fruit belt, changing the climate, as a whole, only as it becomes more equable. The two highlands have opposite relations to the maxima; the one northwest of Saginaw Bay has specially low maxima, while the one southeast

is distinctly higher. The former is sandy and largely covered with barren, denuded jack-pine plains; the latter is lower, more clayey, more cultivated, and probably retains its moisture—the great regulator of climate—better.

Fig. 4, showing the mean temperature, indicates that warmth enters from the southwest corner of the Lower Peninsula and extends up Grand River Valley, while the temperature at Saginaw is rather

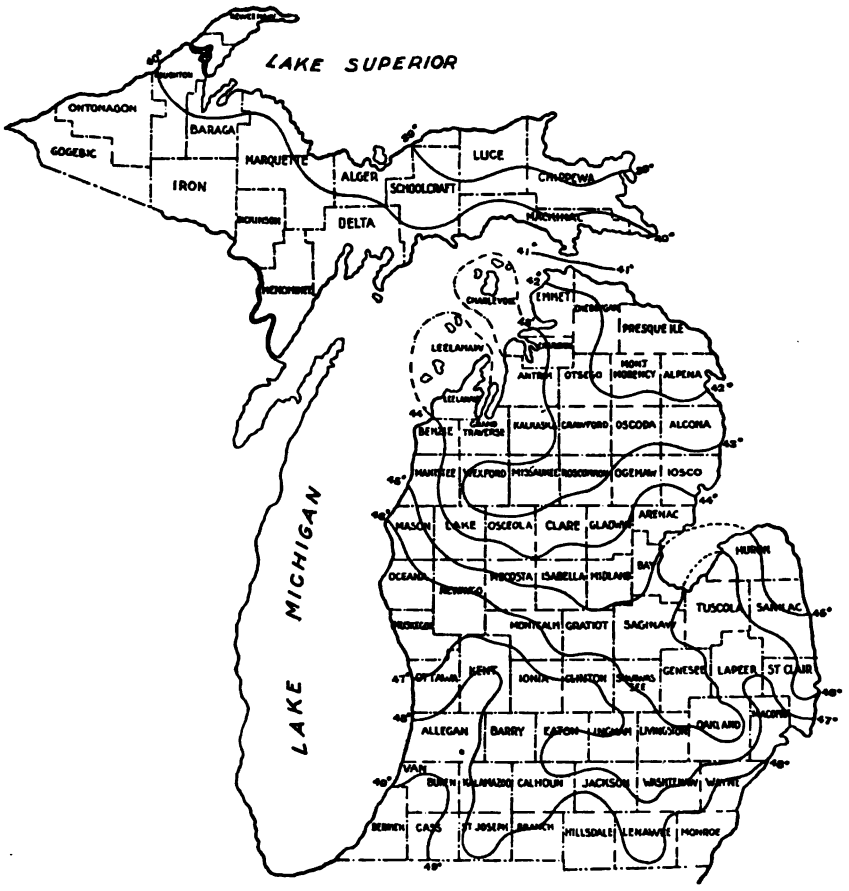


FIG. 4.—Distribution of average mean temperature in Michigan.

colder than it is immediately east or west. The mollifying effects of Lake Erie and Lake St. Clair are also shown in figs. 3 and 4. It is generally supposed that, as stated below, the temperatures of flowing wells are those of the localities given in fig. 4, plus a certain amount, this amount depending on the depth of the well—about 1 degree in 60 feet, but observations give rather higher temperatures in wells less than 200 feet deep. The summer rains may penetrate farther and more rapidly than do the winter snows.

Fig. 5 shows the average rainfall. In the southern part of the

peninsula precipitation and temperature seem to increase together, while in the northern part of the peninsula a line of low precipitation seems to extend from Saginaw Bay to Grand Traverse Bay. It is a fortunate coincidence that the flat, low, clayey, easily flooded Saginaw Valley has a relatively low record in precipitation as well as in temperature, while the sandier western shore has more rain.

The wind has some influence on problems of water supply. Many wells are said to change their level with the wind. This is probably

FIG. 5.—Distribution of average annual precipitation in Michigan

in many cases not directly due to the wind but to fluctuations in barometric pressure. The prevailing winds have another very important effect. Where the prevailing wind is on shore, the shore is more apt to be sandy than where the wind is offshore. A large part of the peninsula has been covered by lakes and the sandy character of the shores and old shore lines that face the west, which is the direction of the prevailing wind, is pronounced. It should be remarked, in addition, that during the hot days of summer a marked afternoon breeze from the lake is a prevailing feature.

LONG-PERIOD VARIATIONS IN RAINFALL.

There is one important feature of the climate, however, on which no light can be gained from Winchell—the variations of the annual rainfall from year to year. This may be learned from the fluctuation of the ground-water level, or the level of the Great Lakes, which observation has shown (see fig. 1) rise and fall according as the general rainfall of the previous years has been more or less than the average. When the rainfall for several years has been below the average there is also a fall in the level of underground water and in the level of the lakes, especially those that have no outlets. Clam Lake, near Cadillac, has varied 16 feet within memory, and Houghton Lake and Higgins Lake are lower than they have been. One will everywhere find reports that the lakes, streams, and wells are lower than they were formerly, and muck plains (Pl. III, *B*) underlain by shells, marking former lake bottoms may be seen. This lowering of lakes and ground water is ascribed to various causes, all of which may perhaps be at work.

In the first place, it is argued that cultivation tends to accelerate the run-off so that water does not have time to soak into the earth. This is doubtless true. On preliminary railroad profiles, for instance, areas are marked "swamp" or even "all water" which are now fertile fields by no means damp. The original Government field notes of the United States Land Office also show areas marked "swamp" which are far from such to-day. Much discussion and many charges of fraud concerning these "State swamp lands" have arisen, but not all such descriptions were by any means fraudulent. Many of these swamps are explicitly described as beaver meadows or as due to beaver dams. The beavers have gone, their dams have been broken, and the swamp has become dryer. Again, loggers' operations are active in clearing out the streams and in cutting out the dams, though they erect dams and obstructions of their own. On the whole, however, the floods, aided by the loggers, have cleared the streams and made them more efficient drainage channels. The more irregular the flow of a given quantity of water the greater its efficiency as an erosive agent.

The next cause to be considered is devastation by fire. Logging operations leave the forest a forest still, but the black scourge of fire which follows strips the ground of leaves, and, worst of all, frequently consumes the vegetable mold that absorbs water like a sponge. The amount of water actually evaporated by a fire is insignificant in proportion to the permanent damage. Most of this fire waste is accidental, but some of it is the result of gross carelessness. I have seen a meadow with the mold of generations burned clean in clearing, leaving only a bare subsoil of sand fertilized with ashes that will yield good crops for a few seasons only and then be leached out. Then comes the plow. Sandy soils still absorb water, some of them having 36 per cent water capacity, but some of the bare, plowed,

A. CLINTON BORING APPARATUS.

B. FIELD OF ONIONS IN DRAINED LAKE BOTTOM: 1,350 BUSHELS TO 1½ ACRES. MUCK PRACTICALLY BOTTOMLESS.

sun-baked slopes of the clay hills are almost impervious to water. Finally, in the extreme lowlands drains of every size and variety, from the farmer's tile drains to the roadside, the township, and the large county drains, accelerate the departure of undesired water.

The time may come when drainage, instead of being down the slopes, will be along them, transferring the water from the hollows to the lower uplands and thus promoting irrigation. But that time has not yet come.

In the second place, there is often supposed to be a general desiccation of the climate, a steady decrease in precipitation. Of this there is no definite historic evidence, though of course in the ice age and immediately subsequent there was certainly more water in all lakes and rivers, though possibly no greater precipitation. Frozen water once covered the country. Legends of what the Indians used to do in the way of canoeing can be easily interpreted, partly by the desiccation due to settlement (which has already been mentioned) and partly by the fluctuations of precipitation and water stage from decade to decade. But as research shows, the general water level has been fairly constant during the century. A period (1886–1896) of decreasing rainfall, however, which has just been passed, has lowered the lakes and caused the wells to fail in a way that has surprised the oldest inhabitants of many of the new towns. It is necessary to go back many years for a similar fall.

SHORT-PERIOD FLUCTUATIONS IN WATER LEVEL.

Sudden fluctuations occur in the Great Lakes and in the ground water which are not regular annual and seasonal fluctuations like those before described, but are more like waves of great breadth, the whole water of the lake basin washing from side to side. An instance may be recorded in which the surface of a channel connecting a small lake with Lake Superior rose and fell about a foot in an interval of twenty minutes. Similar fluctuations occur everywhere in the lake and completely disguise, except to most careful and systematic observation, the minute lunar tides. Sometimes these variations can be distinctly traced to the wind. A strong north wind will pile the water up in Saginaw Bay, and a strong southwest wind will drive it out. A variation of 400 feet in the position of the shore line has thus been caused in one night. Another cause of these variations, often cooperant with the one just mentioned, is a variation of atmospheric pressure over different parts of the lake basin, the water tending to rise when the pressure is least.

Analogous phenomena, probably due to analogous causes, are reported from numerous wells, but as yet have not been subjected to careful investigation. When the wind is in a certain quarter long enough or strong enough, or just before a storm (i. e., at a time of low atmospheric pressure), the water is reported to come

more freely, to have greater head, or to be roily. These phenomena are naturally most conspicuous in wells which flow with no great head, and are analogous apparently to those long noted on Stromboli and Vesuvius, which are said to discharge their lurid contents more freely before a storm. Sometimes these phenomena are attributed to direct connection with the lake. This theory, of course, ought not to be rejected in all cases; but similar phenomena occur so far from the lake that it is safe to assume that in most cases the well fluctuations are due to the same cause as the fluctuations in the lake rather than to the fluctuations themselves. An interesting "breathing" dry well is noted in sec. 7, T. 35 N., R. 5 E., a phenomenon which has been noticed in caves elsewhere in the world.

WELL TEMPERATURES.

Special attention is due to the effect of mean annual temperature on the temperature of wells and springs. It is true in general that the temperature of the water in flowing wells or springs represents the mean temperature of the locality, but there are some qualifications; something must be allowed for the increase of temperature which we find everywhere in going toward the center of the earth.

If the rate of increase shown by the Alma Sanitarium deep and shallow wells gives a true average, we get an increase of temperature of about $(98°-48°=50°)\div(2863-157=2706)$ or 1° in 54 feet, which is very nearly the normal rate of increase of the world, which may be assumed in preliminary reductions. Other wells at Midland, Saginaw, Frankfort, etc., would give other rates down to 1° in 100 feet, but they are for less depths. Water flowing from a driven well 56 feet deep, therefore, might have its temperature raised about 1° above the average for the place, provided it had been flowing so long or in so strong a stream that the temperature of the ground traversed on the way up did not affect it. The effect of the summer's heat and the winter's cold is felt in the ground (as Lisbon and Edinburgh observations have shown) to a considerable depth, the annual variation growing less with increased depth and the time of greatest cold becoming later, so that if the flow is from 30 to 60 feet down the temperature should be actually slightly lower in summer than in winter. Observations by Prof. C. A. Davis, of Alma (T. 11 N., R. 3 W.), show this to be the case in some of the wells there, the water of a well 55 feet deep standing at 52° F. in winter and at 48° F. in summer. Other observations of the temperature of wells require modification to allow for the above factors. But it is certain that the temperature of water from a well 100 feet deep ought not to vary more than 2° F. from the mean annual temperature of the place, and probably in summer, when observations are usually taken, is very near it, the effect of the last winter's cold balancing that of the earth's thermal gradient.

The temperature of deep-flowing wells of small bore is somewhat affected by the earth's heat, e. g., the deeper Bay Port (T. 17 N., R. 9 E.) wells; but it would certainly be incorrect to take anything near (338 ÷ 56 =) 6° from their temperature (of 47° F.) to obtain the mean temperature of the place. Again, as the winter temperature is felt to a depth at which no effect of a particular cold day or week can be detected, so a series of extra cold or extra hot years will modify the temperature to a depth where no trace of annual fluctuation can be observed. In a similar way any permanent factor, like the presence of a boiler house or a cellar furnace, may modify the temperature of a flowing well to a considerable depth. A good illustration tion is afforded in a flowing well at the sawmill in Rose City (fig. 8), which is deeper and on ground 25 feet lower than the wells of the town; but this is not sufficient to account for nearly 7° greater warmth over the hotel well.

SUPERFICIAL GEOLOGY AND TOPOGRAPHY.

GENERAL DESCRIPTION.

The contour map of the State (Pl. I) shows two high areas, to the southeast and northwest of Saginaw Bay, respectively, which are also brought out in fig. 6. Winchell has laid down the following proposition (Tackabury's Atlas of Michigan, p. 14): "The actual topographical and hydrographical axes of Michigan and the whole lake region are the resultant of two forces—a glacial, acting from the northeast, and a stratigraphical, acting along the lines of strike of the rock formations." This is what he calls the diagonal system in the physical features of the State. While this statement may be true in a broad way, it must be seriously modified to express the facts of the case. It ignores the shore lines of the old lakes, elsewhere recognized by Winchell as an important factor, and it is really as approximately true that the various positions in Michigan where the glacial front halted, i. e., the moraines, and more or less at right angles to the direction of its motion, are the dominant features, and that next to them come the lines of halt of the lakes succeeding. The old stratigraphic lines of rock outcrops are very obscure.

In a broad way, as described by Winchell, the consolidated rocks are arranged in concentric circles, surrounding the coal measures which occupy the center of the State. (See map, Pl. VI.) During Mesozoic and Cenozoic time these were eroded, but two sets of strata proved to be sufficiently resistant to become topographic features of the first class. The Marshall sandstones (Logan conglomerate), the Helderberg in the southern part of the State, and the Traverse limestones in the northern part of the State, tended to make ridges, as may be seen in the cross section (fig. 10). Inasmuch as the softer coal basin rocks were thus surrounded by harder strata this harder rim

would be cut across in some way. The evidence seems strongly to indicate that the channel draining the central basin went off, not as Spencer has suggested, through the Saginaw Valley, but past Manistee toward the great valley, now occupied by Lake Michigan, which was excavated in the softer shales, gypsum, and salt, and marks the Salina (Lower Helderberg). The circumvallation was probably somewhat broken in the region of Saginaw; at any rate, the outer circle made by the Helderberg (Traverse, Dundee, and Monroe limestones) was passed. Thus the ice flood, advancing from the Laurentian highlands, was deflected by this circular double rampart and passed in two great lobes—the Michigan and the Huron-Erie respectively—west and east of it. As the ice reached its maximum, however, it broke over the outer rampart and passed down the present valley of the Saginaw. At the greatest extent of the ice Michigan was completely and undoubtedly smoothly covered with it. Of inter-Glacial periods, with accompanying forest beds and other deposits interstratified with the till, the evidence is not very clear in Michigan. This is a point of importance, as such inter-Glacial beds might be water-bearers. The red clay described by Rominger may be such an inter-Glacial formation. Wood, however, is not uncommonly found in boring wells, as at Vassar, at Paw Paw, in Huron County, and elsewhere.

A bed of gravel or bowlders, which is porous compared with the overlying till, generally comes just above the bed rock, and the till itself is sometimes composed of alternations of gravelly clay and sand or quicksand. Such alternations and buried wood might be explained by the oscillations in the advance and retreat of the ice front and by the shifting of the ice streams from season to season, decade to decade, or century to century. It should be remembered, too, that caution must be used in interpreting the results of mere borings. For instance, a 3-foot seam of sand, reported in a 2-inch boring near Saginaw, when a shaft was sunk proved to be merely an irregular, nearly vertical seam.

It can not be said that below the present surface of the drift such an oxidized and eroded surface has been detected as would plainly imply an inter-Glacial period of considerable duration. Such a surface, especially near the center of motion, would often be swept away and obliterated by the readvance of the ice, and I have seen few exposures which indicated it, for erosion has not gone very deep since the last disappearance of the ice. The cliffs north of Frankfort, and particularly the valley of the Au Sable, would seem most hopeful places for the search. I should be puzzled to know how to make sure of its existence from a mere well record, unless, perhaps, such a zone being reached might be recognized by the yielding of softer water than that of the strata above.

The comparative lack of evidence of inter-Glacial epochs in Michigan, compared with States farther south, can not, however, be wholly

accidental, and the advance of the ice may be likened to the tides rising and falling on the shore. The highest tides of spring extend farther than the others, and the intervals between such extreme tides are at least half a year. Lesser high tides occur twice a month, and the common tides ebb and flow every day. So, down the beach, areas but rarely reached by the waters and uncovered most of the time, adjoin those generally covered by the waters. Thus, along the Ohio River—the line of the greatest extension of the ice—its presence must have been comparatively brief and its visits few, while in Michigan, nearer the source of the ice, the inter-Glacial periods may have been partly or wholly absent and certainly must have been shorter. When the ice finally retired, a lobed arrangement of the ice front—two large lobes on each side of the Marshall circumvallation and a smaller one, the Saginaw lobe, passing directly over it—were conspicuous and remained the most important features in determining the topography of the State. (See map of the Pleistocene deposits, Pl. II.)

The general theory is that the ice retired first from the higher lands; the Saginaw ice lobe, therefore, retired first, and bounding it on each side were two deeply reentrant cusps, which may be said to be the topographic axes of the State. Naturally, streams issued from such cusps, draining away the water from the wasting glacier, so that the typical form in which cusps appear is that of a stream valley, much wider than the present stream, charged with gravel and bowlders—valley trains—and heavily belted with moraines. This concentration of till and detritus on the highest parts of the rock floor naturally forms the highest parts of the State (see fig. 10).

The eastern cusp follows fairly closely the dividing line between the drainage into Lake Erie, Lake St. Clair, and Lake Huron (direct), and the drainage into Saginaw Bay and Lake Michigan. It, and also the other cusp, is marked by a belt of country crowded with lakes. Of the western cusp, Mr. Leverett thinks that he can determine the moraines on the Michigan side from those on the Saginaw or east side, by the fact that the latter contain many more pebbles of a bright red jasper conglomerate.[1]

Thus, at the extreme southwest of the State, where the cusp first entered, Mr. Leverett refers to the Saginaw lobe, because it bears many red jasper-conglomerate pebbles, the morainic belt (see Pl. II) which passes northeast from Niles and goes through Kendall, in the northeast corner of Van Buren County. Therefore the first position of the cusp would lie between it and the stronger ridge just west, which undoubtedly belongs to the Michigan lobe and is known as the Valparaiso. In confirmation, Mr. Bate, a surveyor of much experi-

[1] My own observations agree so far as they go, but the fact is singular. The conglomerate and jasper in question appear to come from the original Huronian area on Thessalon River in Canada, and one would think that they would find their way rather into the Michigan than into the Huron-Saginaw lobe.

ence in the region, states that the red jasper-conglomerate is abundant in Montmorency County, but scarce or absent in Otsego County, except near the eastern line. It is to be noticed that on the map (Pl. II) these moraine belts have their separate color, and the more important areas of sand and gravel deposited by streams draining the ice front are also delineated, although many smaller areas of gravel and sand and stream channels are, for the sake of clearness, omitted. A different color is devoted to those areas over which the ice front retreated more rapidly, making less conspicuous ridges.

Both cusps were evidently guided by the higher land of the Marshall sandstone outcrop. As the eastern cusp worked northeast the upper valleys of the two St. Joseph rivers, the Tiffin (whose drainage area has been preyed on by the Raisin), and the upper Huron River above Dexter, which probably drained off at one time past Adrian and possibly earlier found its way into the Ohio, were successive outlets of discharge. Farther northeast the drainage has been largely rearranged, though the upper parts of the Clinton River, and later the northern forks of the Flint River, the Cass River on the Saginaw Valley side, and the Black and its branches on the other, served for a time. The old summit swamp referred to by Taylor[1] may also be mentioned, and in Huron and Tuscola counties a number of channels are known which evidently drained the ice front but are too numerous to be indicated in a general map. High deposits near the angle are found at Metamora, between Deanville and Brown City, and near Verona Mills.

For the other cusp Dowagiac Creek served at first and, with St. Joseph River, poured into the Keokuk that vast expanse of gravel which is found in its upper reaches in Indiana. Then passing north, through a belt full of lakes, down the valley of the Thornapple, it may be followed up the valley of Flat River, and past Mecosta into the Muskegon Valley. In the Muskegon Valley there is a stream which, first by way of Mecosta and Barryton and then by the main stream, received the cusp drainage for a considerable time. Thus the cusp may be followed into Oscoda County. From this point on the original cusp-drainage lines have again been so disturbed and reversed that it is hard to trace them. Probably the high points near Otsego Lake were at one angle. An old channel seems to pass near Valentine Lake. But the ice soon retired and allowed the water to flow freely all around the peninsula.

The lines of retreat of these cusps are bordered with moraine hills, composed of the débris left by the ice front where it tarried long or readvanced. Moreover, the ranges of moraine hills are crowded together and are higher toward the lines of cusp retreat, for, these hills being nearly parallel to the direction of ice advance and retreat, a general advance or retreat in the ice front made only a slight differ-

[1] Geol. Soc. Am., Vol. VIII, 1896, p. 31.

ence in their position. Of course such moraine belts are studded with small tarns—deep lakes of water caught between the various rows. Some of the moraines, especially the higher ones, which do not mark readvances so much as the edge of the cusp dump grounds, are exceedingly sandy, with hardly any clay, and in such cases the lakes fre-

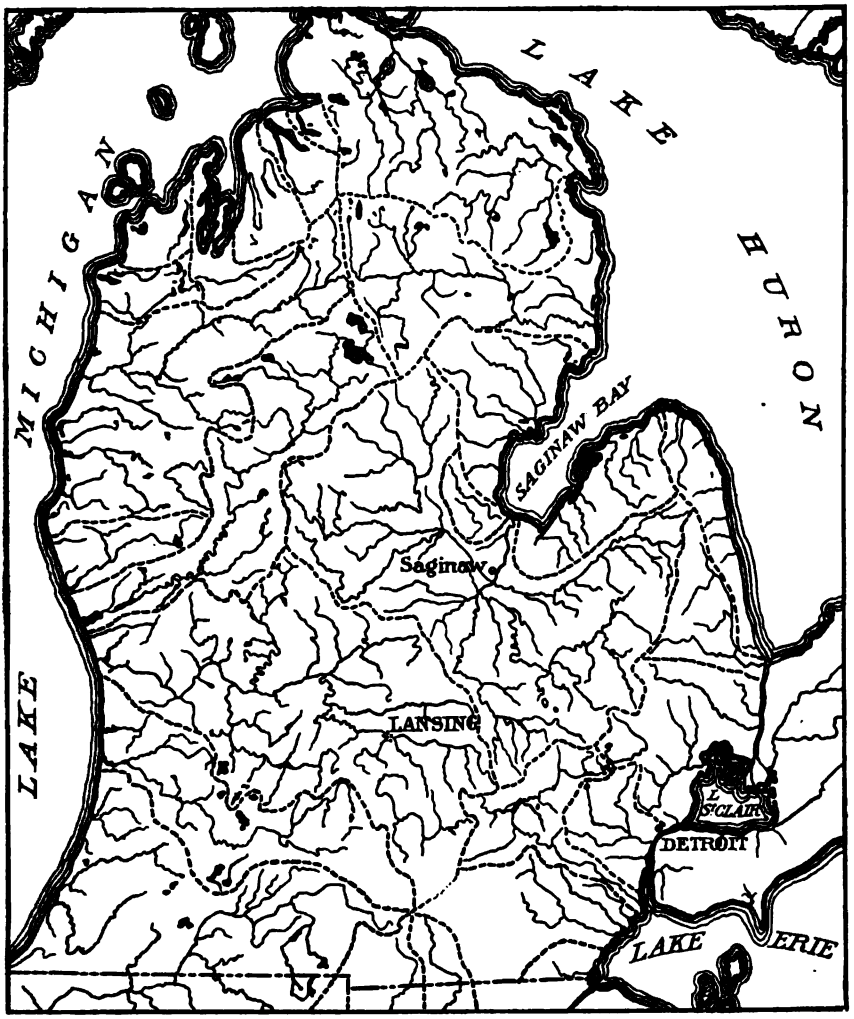


FIG. 6.—Sketch map of the drainage of Lower Michigan.

quently have no outlets. Lakes of another variety are formed in the following way. The moraine belts are frequently cut through by channels which served as vents for streams coming forth from the moraine. Only a few of these channels are indicated on Pl. II. One, well marked, is formed by the upper valley of Willow Creek in T. 16 N., R. 13 E.,

Huron County, which also has branches. Near Harrison, in Clare County, are others, some of the finest that I have seen. Entering the valley of the South Branch of Muskegon River there are others, in T. 14 N., R. 8 W. But many that I have noticed I have not yet been able to connect into significant channels. Now, while sometimes the old channels abandoned by the streams from the melting ice sheet stand perfectly empty, more often they are occupied by marshes at least, and not infrequently by lakes, the hollows occupied by the lakes having been made by the melting of a lump of ice (kettle-holes), by irregular settling of the sand, by an original sand bar in the stream, or by delta sand washed in by some tributary Glacial or post-Glacial stream. Many of the long, winding, and generally shallow "crooked" lakes, are thus located.

It is obvious that thus to uncover and drain the higher lands must produce, first of all, a peculiarly unnatural form of drainage. A marked type of river valley is thus produced. (See fig. 6.) All the larger streams begin to flow to the south, starting from some of the lines of drainage from the ice. They run along the ice front opposite a moraine, which, as a comparison of fig. 6 and Pl. II shows, is often a divide, and receive, of course, some tributaries from the north, which usually flow in valleys of ice outlets, but also receive a great many streams, perhaps smaller individually, which flow down the back of the moraine last deserted. At some point in their flow they reach the old lake shores, unless they are first diverted by some stream which has cut back through the moraine, and thence flow more directly down to the present lake. This accounts for two of the most striking facts in studying the drainage of the Michigan streams, namely: (1) The principal stream valleys curve so as to be concave northward; (2) the principal streams receive more numerous tributaries from the south. The Manistee is a most striking illustration of this tendency, while the Bear and the Betsie (Aux Becs Scies), near by, are similar. But so far as the curve is concerned, hardly anything can be more striking than the way in which the Tittabawassee on the one side and the Cass on the other curve around Saginaw Bay to me in Saginaw River.

The simplest and most natural form of drainage occurs where a smooth, tilted plain is lifted above water level. There all the rain water can run straight to the lake, or allowing for minute undulations, gather into small streams which run parallel to each other down the slope. This simple type of drainage is almost perfectly and typically illustrated along the east side of the Thumb in Huron and Sanilac counties, and it may be seen in small areas elsewhere. I have noted in one section of Elmwood Township (T. 14 N., R. 10 E.) four distinct parallel water courses traversing diagonally a section of land a mile square.

It is obvious that the type of drainage produced by first opening the

higher lands to drainage is just the reverse. Hence it is subject to rearrangement. The Lower Peninsula of Michigan might, were it closely and accurately contoured, become a classical land for the study of the phenomena of stream capture. One can see it taking place even now. Ditches are found of which one end drains into one river valley, and the other end into another river valley (e. g., south of Bad Axe, T. 16 N., R. 12 E.), but little by little one stream will come to drain the ditch more than the other.

Instances of reversed drainage are therefore not uncommon. One instance, previously cited by students, is that the lower part of Dowagiac Creek has been reversed so that the St. Joseph now flows up it and to the lake that way, instead of south to Keokuk, as formerly. Another clear case is in Huron County, where the upper Willow occupies a valley once a Glacial outlet by way of the Cass to the south. In fact Shebeon, Pinnebog, and Pigeon rivers, especially the last, are encroaching on the Cass and will probably deprive it of the North Fork that comes down from Huron County. The Pigeon, using a Glacial channel to the Cass that it has reversed, has already effected an entrance into the main valley of the North Fork of the Cass. Man is assisting in this readjustment, for it is obviously to his interest to reclaim the rich lands of the swamps and the drained lakes along the shortest possible lines.

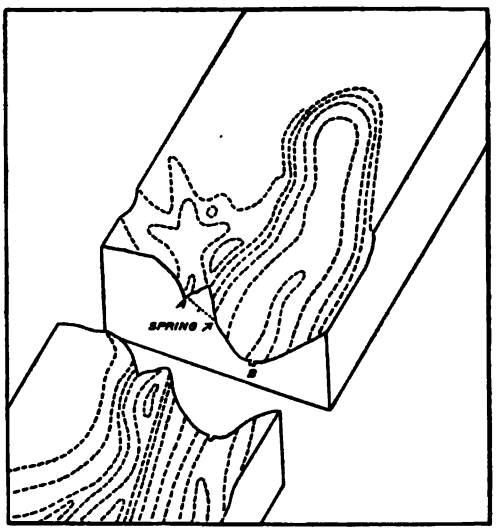


FIG. 7.—Diagram illustrating method of stream capture. A, dry channel; B, deeper encroaching channel with springs on its sides.

The streams which drained the ice front have many features that make them an easy prey to pirate streams. In the first place, flowing along the higher lands, with a circuitous course, they have easy grades, which weaken their power of erosion. In the second place, the ice streams, of which they are now deprived, carved valleys much too large for them and brought down much débris—more than the present streams can handle; and much of the débris was so coarse that there is a constant tendency for the water to percolate through the sand and gravel and do no erosive work whatever, except some little chemical erosion, which leaves the beds even more permeable than before. This is quite noticeable in the North Fork of the Cass, the bed of which

shows that its erosive work is nearly at an end, for vegetation is pressing hard upon it. Now, as the vigorous headwaters of the pirate streams push into the plain of sand and gravel of such an old valley they naturally lower the water level, and the water of the valley is drained away by seepage through the sand and gravel. The annexed figure (fig. 7) is an ideal illustration of lateral seepage from an actual case; fig. 8 is also instructive. In fig. 7 the valleys are nearly parallel. In fig. 8 the attacking stream is working in at right angles to the ancient valley course. In many parts of the State one will come across valleys where, judging from the vegetation, there is now rarely any surface-water erosion, as the water sinks in and is absorbed by the sands and gravels (e. g., sec. 34, T. 24 N., R. 2 E.).

In some parts of the region of overwash sand and gravel kame plains (e. g., around Harrison, T. 19 N., R. 4 W., and Grayling, T. 26 N., R. 4 W.) one may have to sink 100 feet or more in surficial deposits before reaching water, and may then reach a real surface seepage water, while even the deep valleys are dry most of the year, so perfect is the subsurface drainage.

LAKES OF LOWER MICHIGAN.

The lakes of Michigan are numerous. Estimates of their number vary from five to fifteen thousand. There are twenty-five in the township of Grattan (T. 8 N., R. 9 W.) alone. They are of great importance as direct sources of water supply, as reservoirs which tend to steady the stream flow, and, finally, when they disappear, as furnishing the black muck soil, with a shell-marl subsoil, that has proved wonderfully adapted to celery and other culture. The accompanying illustration, Pl. III, *B*, shows a field of onions on such land. It is the second type of lake—the shallow lake of the interlobate drainage—which is especially likely to be thus filled. The remarks concerning the lakes of the Kalamazoo River Basin, page 24, apply very nearly to any other part of the Lower Peninsula above the line of the old lake extensions, colored blue on Pl. II.

The following description has been taken from an unprinted paper, by Prof. C. A. Davis, read before the botanical section, Michigan Academy of Sciences, giving a graphic description of these pools:

"The lakes of the State, exclusive of the Great Lakes, cover an area of 1,225 square miles, or more than 784,000 acres, or about $\frac{1}{150}$ of the total area of the State, and they are so distributed that there is hardly a botanist in Michigan who can not readily reach one or more of them.

"The small lakes, particularly those of the Lower Peninsula, are commonly depressions in the drift, shallow and not of large extent, frequently partially filled in around the margin with the remains of former generations of plants, so that many of the typical features of lakes of hilly or mountainous regions are partly suppressed or entirely wanting. These lakes belong to recent geological time, and this undoubtedly accounts for some of their peculiarities. By far the

larger number of them exhibit the following features. A small sheet of water, roughly elliptical in shape, bordered by a marshy area of varying width, or on two or more sides by low, abruptly sloping, sandy, or gravelly hills. The marshy tract is frequently wider on the south than on the north side, and its character varies from a quaking bog at the inner margin through a sphagnous zone into a swamp, in which the prevailing trees may be tamarack, cedar, or spruce. The plants of the sphagnum zone are characteristically those of the boreal-life zone, and in such lake margins we find northern plants reaching their southern limits. The quaking bog is usually a lakeward extension of the shore plants and is a closely woven turf of the roots and root-stocks of various species of *Carex*, *Cyperus*, grasses, and at its outer margin consists sometimes of *Typha latifolium* and *Sparganium eurycarpum*. In the larger lakes the marshy border may not extend entirely around the margin, but it is usually noticeable along the southern shore, where it may be of considerable extent, while the rest of the shore is entirely without it."

Most of the lakes of Michigan belong, in origin, to the two classes already described, i. e., they are either inclosed between moraine ridges or are left as pools in the kame plains of sand and gravel. Lakes of these two classes are usually more than 750 feet above tide. In general, the regions of numerous lakes are the regions of crowded moraine belts, and they may be approximately traced in this way. But there are two or three other classes of lakes that deserve mention.

First, there is a class of lakes which arise from the erosion of limestone into caves that finally tumble in and produce sink holes. Though there are some indications of sink holes in the Carboniferous limestones, lakes of the sink-hole class are, so far as known, practically confined to the lower Devonian limestones (Traverse and Dundee) and occur only in the extreme southeast (Ottawa Lake, T. 8 S., R. 6 E.) and northeast (e. g., sec. 32, T. 33 N., R. 6 E.) of the State.

Second, there is a class of lakes which may be in part in rock or moraine basins, but which owe their distinct existence to the fact that the Great Lakes now, or at a higher stage of water, have built sand bars across the mouth of long bays and have thus cut them off from the main body of water. Such lakes are frequently less than 25 feet above the water level. A good illustration is the lake to the right in the view of Sleeping Bear Point (Pl. V), or Pine Lake, near Charlevoix, which is now reconnected by an artificial channel with Lake Michigan (T. 34 N., R. 8 W.), and it is easy to see, from the map or from Pl. IV, that Grand Traverse Bay might be converted into such a lake.

Some of the lakes are nothing more than old river valleys flooded by the tilting of the earth's crust and the consequent encroachment of the lake on the land. This is a class not clearly separate from the others. Such lakes occur by the score along the west coast of Michigan from Kalamazoo River to Frankfort, and seem to be submerged

river valleys,[1] but the bars built across their mouths, are as in the second class.

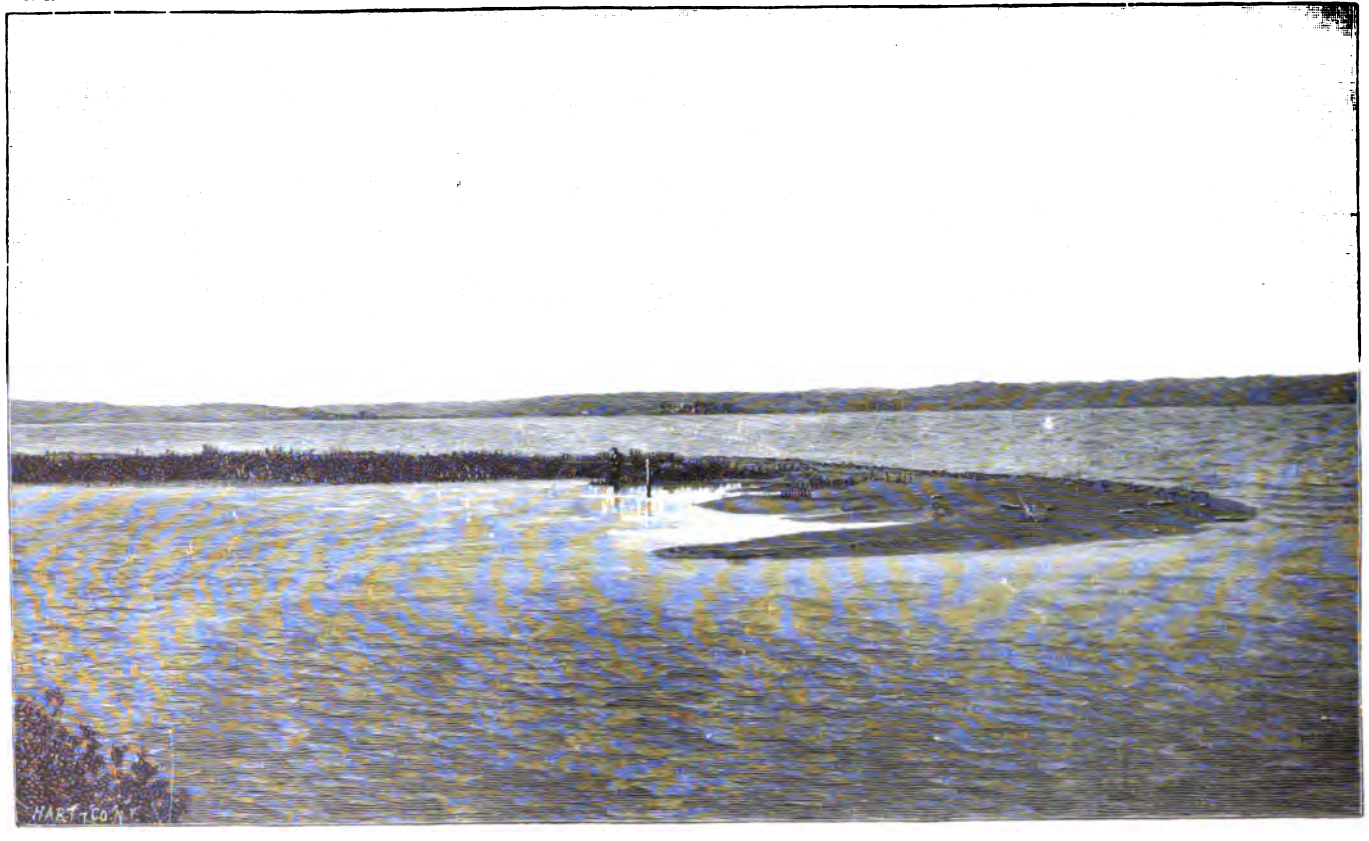
If, as Professor Gilbert has said, the land is rising to the northeast at the rate of 5 inches a century for each 100 miles, it is easy to see that such a stream as Saginaw River will also tend to be ponded back; and, in fact, so far as current is concerned, Saginaw River is now but a long, narrow lake.

When the ice lobes retired so that the heights of the rock surface lay in front of them, crowned by a heavy moraine, the water gathered in front of them in great lakes. The débris brought by streams in the ice was, in this case, laid down more smoothly and stratified with the clay that accompanied it. Thus the topography of these moraines laid down under water is far more gentle than that of the earlier ridges. On the east side the lake in front of the Huron-Erie lobe, as shown by Gilbert in the Ohio reports, drained off past Fort Wayne into the Maumee, and the waters of this lake level were about 220 feet above Lake Erie or 785 feet above tide level. Toward the north the beach lines are at a somewhat higher level, the change to water-laid topography occurring somewhere about 800 feet above tide.

In the center of the State a lake was penned up in the Saginaw Valley, as recognized by Winchell and Mudge, and flowed down Grand River. The highest water of this lake, as seen in the sandy gravels around Alma and Pompeii, seems to have been about 760 feet above tide, so that, as the swamps south of Ashley are about 85 feet above Lakes Michigan and Huron (i. e., 667 above tide), the water would have stood about 100 feet deep in the channel, unless it has gradually scoured it down to present level. It is no wonder, then, that the drift was scoured down to the rock at Grand Rapids and Ionia. It flowed into the lake which had been similarly formed in the lower end of Lake Michigan and was draining over into the Mississippi by the recently reopened Chicago outlet. This lake was at first at least 90 to 100 feet above the present lake level, or 680 feet above tide, and probably more.

As the ice retired the lake east found a number of drainage channels across the Thumb through Sanilac and Huron counties, as indicated in Pl. II.[2] Finally free communication was opened around the Thumb in Huron County. This produced a slight but preceptible drop in the water level of the eastern lake, but thereafter it remained relatively permanent, and is marked by a well-defined gravel line, not perfectly horizontal but rising a little to the north. This may be explained by the removal of the attraction of the ice mass to the north, or by a subsequent tilting. Around Ypsilanti (T. 3 S., R. 7 E.) it is 750 feet above tide, while in Iosco County (sec. 30, T. 22 N., R. 6 E.) it is about 775 feet above tide, and in Huron County, north of Verona (T. 16 N., R. 13 E.), it is about 774 feet above tide.

[1] See article by Winchell in Harper's Magazine, Vol. XLIII, July, 1871, pp. 284 and 285.
[2] See also article by F. B. Taylor, Bull. Geol. Soc. Am., Vol. VIII, 1896, p. 31.



DUTCH POINT SAND SPIT, GRAND TRAVERSE BAY.

The fall from this level, whether due to the opening of a new outlet in New York, or, as is possible, to freer communication into Lake Michigan, was rather sudden for the first 50 to 75 feet, for we find that there are but few, and these local, traces of sand ridges in this interval, that the soil is clayey, and that the general course of the streams is directly down the slopes toward the lakes. The drop of the next 25 feet was comparatively slow and marked by a broad sand belt, and at a slightly lower level (650 feet in Huron County) was another marked halt. Then still lower, about 25 feet above present lake level in Huron County and about 17 feet in Iosco County, was a long stay, during which many bays were filled in or bridged by sand spits, so as to form lakes.

The history of the western side of the peninsula is perhaps not so eventful as that of the eastern side, given above, and is not so familiar to me. The belt of lacustrine deposits belonging to the Great Lakes is naturally narrower, being only from 60 to 125 feet above the present lake level, but there were many large lakes. Kalamazoo County, for example, has been divided into eight "prairies," viz, Prairie Ronde, Ground Neck, Genesee, Grand, Tollands, Gull, Dry, and Climax. These prairies, with their black loam soil, are probably old lakes. (See p. 64.) The marked change of grade in Kalamazoo River near Kalamazoo, brought out by Mr. Horton's table (p. 37), is probably due to the river crossing such an old lake bottom, where the grade is barely enough to keep the water moving.

Similarly, Higgins and Houghton lakes seem to be but shrunken remnants of a large lake drained by the Muskegon, which covered a large part of Roscommon County when the ice lay on both sides of it.

There are high terraces around Traverse City and in similar situations, which show that the ice front once dammed up a lake at a much higher level in that region, a lake whose water level was as high and at first higher than that on the east side of the peninsula, and which probably drained off southwest. The study of this lake in all its stages would make a very interesting problem for the glacialist. The map (Pl. II) without doubt needs much correction in Leelanaw County. It is obvious that the ice projected in a long tongue into Lake Michigan and retired very slowly, much more slowly than from the highlands. From the retreating cusp sprang large rivers, draining into Lake Michigan, whose channels were heavily lined with coarse sand, gravel, and bowlders—the so-called valley trains. From Cadillac to Elmira the line of the Grand Rapids and Indiana Railway is mainly through sand.

WELLS IN THE PLEISTOCENE.

Before taking up in detail the application of the facts noted above to the study of the water supply of the various districts it may be well to call attention to certain general statements:

1. Clayey regions do not yield water freely. This applies first to

lake clays, and in slightly less degree to bowlder clays or till, known among drillers as "hardpan." Regions of this type are mainly included in the sections colored blue and light buff on the map (Pl. II).

2. Sandy regions will at some depth yield a supply of water. But a distinction must be made between the sandy belts of the lake-washed region, in which the sand and gravel are a very dry, superficial coating to the clay beneath, liable to contamination and likely to fail altogether in dry seasons like 1895, and the heavier sand and gravel regions, which represent drainage from the ice sheet, such as the great gravel plains of the Muskegon, the Manistee, and the well-named Au Sable. In such plains water is found at considerable, often at great, depths, but the supply once reached is abundant. The heavy sand regions are mainly colored brown and crosshatched on the map (Pl. II).

3. The alternate advances and retreats, whether of ice or of lake, have tended to produce an alternation of deposits more or less clayey.

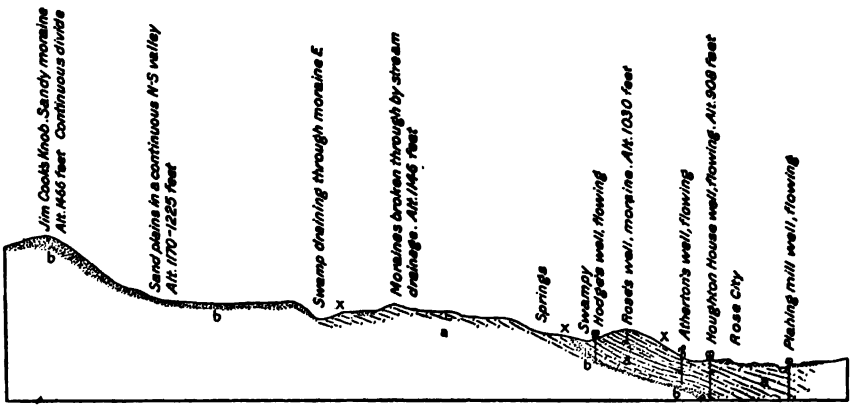


FIG. 8.—Profile near Rose City, Michigan. a, impervious beds—clayey till; b, pervious beds—sand and gravel; x, springs. Horizontal scale, 1 mile=1 inch; vertical scale, 400 feet=1 inch.

It is easy to see that in the case of a lake such deposits will dip slightly from the lake margin toward the lower, deeper parts of the lake bottom. But the same thing is true also of ice. The ice front would retire from the highlands, leaving an apron of gravel in front, and then a little change of climate would produce a readvance, in which it would roll up the apron ahead of it or roll over it and deposit a gravel clay (ground moraine) upon it. Or, if it retired so far as to leave a lake between it and its past position, it might push the lake clays on top of the shore gravels of this lake. That is in many cases what has occurred. In some cases, of course, the pervious bed is entirely destroyed; but often the pervious bed remains as a good source of water, and has head enough to produce a flow. Close to the lakeward side of prominent moraines, shown upon the map (Pl. II), flows from the drift may be expected. The cross section near Rose City (fig. 8) illustrates this principle. In the midst of moraine regions

there is confused and broken topography, springs are common, and there are often small groups of flowing wells in the low grounds.

4. The ice was very likely to leave some gravel in all sheltered, i. e., southern sloping, parts of the rock surface or the valleys therein. If the rock itself was not impervious there was some circulation of water along it which leached out channels. Thus it is the rule, though not without exceptions, that just above the rock surface there is a water-bearing stratum.

METHODS OF SINKING WELLS.

While the wells in the rock have been almost invariably drilled, there has been considerable variety in the method of putting down wells in the drift, and a brief recapitulation may be suggestive.

First, of course, are the dug wells. Where experience has shown that many bowlders and stones are likely to be encountered, digging will probably prove the most economical method. Wells are dug 2 feet or more in diameter, and are variously cased. From all parts of the State come complaints that wooden casing soon rots and makes the water foul, and is almost always used longer than it ought to be.

Another form of casing is stoning, where stones are plenty. The disadvantage of stoning is, however, that it does not keep out the surface waters.

Where stone is scarce brick casing is often used, also large crocks, or sewer pipe about 2 feet in diameter. Properly sealed against surface water, these make excellent casings, though fragile and likely to be cracked by uneven settling of the earth.

A plan followed in some extra deep drift wells and worthy of wider adoption, is the use of a boiler plate shield and the cementing of the well as it is dug. Mr. E. R. Phillips has his well in Bay City cemented down to its bottom and a bed of charcoal and clean sand therein—an excellent plan for those who must use wells in unsatisfactory localities.

The disadvantage of combining a dug basin with some other form of well, and the various disadvantages of a lack of thorough casing are described on page 72.

Another kind of well is the driven well. This is a great favorite in the sandy and gravelly districts of the areas covered by Glacial drainage deposits (colored brown and crosshatched on the map, Pl. II). In the heavy clays of the lake clay areas (colored blue on the same map) it is quite common to use an earth auger and bore down, and this may be combined with driving where necessary.

The chief difficulties encountered are stones too large to be pushed aside, which have to be dynamited, quicksand, and fine sand, like that of an hourglass, which runs in faster than it can be pumped out. In going through strata carrying quicksand, work should be continued night and day without interruption. I do not know that artificially freezing or cementing the quicksand bed has ever been tried in

the State, though it would be effective. It would seem that especially in case of quicksand, a mode of sinking wells illustrated by Pl. III, *A*, might prove very effective. This method consists of forcing down, in a smaller pipe within the casing, a current of water, under a very strong head (sometimes steam is also used), which scours out the soils and lets the casing drop as it is tapped. There is thus no opportunity for the sand beyond the reach of the very strong current to pile in. These quicksand beds sometimes contain water, but the well becomes easily clogged if its point is near quicksand.

EASTERN SHORE DISTRICT.

For the purpose of detailed description the State may be divided into seven sections.[1]

In the eastern shore district is included nearly all the country which slopes off to the east from the land water-laid moraines along the eastern part of Huron County down to Monroe. The surface soil is predominantly clay. This is varied by strips of sand along the streams, composed of successive deltas and old shore lines more or less parallel to the lake,[2] along which the ridge roads often run. On the clay no surface wells can be obtained and deep wells prevail. On the sand ridges shallow surface wells can be obtained, but are likely to fail in dry times and are, besides, at all times liable to pollution. In boring down an impervious lake clay or a gravelly clay, generally known as hardpan, is found. Interlaminated streaks of gravel are few and not uniform, except that generally just above bed rock there is a porous water-bearing seam. In the extreme south of this district through Monroe County, from Ottawa Lake to Sibleys (an area colored red on the map, Pl. VI), limestone outcrops are found, and the drift is accordingly shallow, but in passing to the northwest there is very soon encountered about 80 feet or so of the blue and gravelly clay. Where this clay overlies the limestone sulphureted hydrogen, which may also spring from the decomposition of the sulphide of iron in the drift, is generally accumulated, and the deeper wells—the so-called sulphur springs—are heavily charged with it. Where black shale underlies—and there is black shale both above and below the Berea grit—burning gas is very likely to accumulate, and often excites surprising hopes. Most of the deeper wells in Wayne are charged with one or the other of these two gases, but no large permanent supply can be expected from them, though in many cases they might for a time furnish a house or two with a convenient fuel. Flows of water from gravel beds are not uncommon throughout this region, and the number and strength of flows increase from the shore back toward the moraine.

[1] After making these sections I noted that there was a striking parallelism between the regions into which I had divided the State and those into which Professor Wheeler had divided it for study of floral distribution.

[2] In Huron County the markedly sandy strips are 20 to 25, 68, 98 to 118, and 163 to 193 feet above the lake.

There, too, the section of the drift becomes less monotonous, and there are more interlaminated gravels. At about 750 feet above tide, on the border of the moraine, on a line along through Britton, York, Milan, Ypsilanti, Northville, Birmingham, and Rochester to North Street, back of Port Huron, one may be reasonably sure of striking water which will rise nearly if not quite to the surface of the ground and frequently overflow. The water of these wells—e. g., that of the Ypsilanti waterworks—is of excellent quality. Farther down the slope the drift beds are less porous and the water, if obtained, is likely to be too highly charged with gas and mineral for comfort.

Through this district, therefore, the sources of water supply may be summarized as follows:

(1) Lakes. Only the Great Lakes are of practical importance and are the only satisfactory supply for large towns.

(2) Surface wells. The wells are generally very shallow and exhaustible. Wells from gravel or sand "pockets" in the clay are very uncertain, but are likely to flow for a time. The Pagoda spring of Mount Clemens appears to belong to this class, but yields more freely than is usually the case. Toward the upper margin of the district the supply is more abundant.

(3) Wells from base of drift. These are almost always present; the supply is ample and the flow probable. They are free from contamination, and are somewhat highly mineralized, but probably not to a degree to render them useless.

SAGINAW VALLEY DISTRICT.

In this district is included the drainage of Saginaw River and part of the surface drainage—about to the 750-foot line and including the part once covered by Lake Saginaw. The rock surface is exceedingly variable. The old coal measure plateau was cut up by gorges 100 to over 200 feet deep, which are more extensive than can be shown on the map (Pl. VI). But the present surface is flat and is varied only by the valleys which the larger streams have cut from 10 to 30 feet below the plain. First with moraine till, and then with the lake clays, the rough rock surface has been plastered nearly smooth. Thus the depth of surface deposits is not uniform, varying from even 0 to 500 feet, but being generally about 80 to 100 feet. Finally, sand ridges frequently occur about 25 feet above the lake, then again, as near Hemlock City, about 70 feet above the lake (655 above tide), and again about 160 feet above the lake (742 to 766 feet above tide), as at Alma, Ithaca, Gagetown, and Cass City.

These sand ridges yield surface water, easily exhausted and liable to contamination. On the clay lands between them the farmers have to go deeper for water, and rarely fail to find it. In most places there are beds of quicksand, which yield water under the clay and very often gravel. Waters from these horizons always rise well, and in

many places flow, especially near the 700-foot contour. The quicksand wells, however, easily clog up and are short lived. The quality of the water is not so unexceptionable as the quantity. It is generally hard and not infrequently somewhat mineralized. But throughout all this region as good water, with as good or better head, can usually be obtained from underlying sandstones.

To the southeast in this district the drift coating is very thin, from 0 to 40 feet, and outcrops in the streams occur; but toward the west the coating becomes thicker. Thus, at St. Johns it is 141 feet deep; at Midland, 198 to 300 feet; at Mount Pleasant, 250 to 350; at Coleman, 300; and the greatest known depth of drift in this district lies at Alma, 495 feet. To the northwest in this region it will be exceptional cases and exploration for other things than water which will lead wells to rock. Especially is this true since ample supplies of flowing water can generally be obtained from the quicksands, which are very difficult to drill through. It will be noted, moreover, that this part of the region lies in a southwest direction from the gypsum quarries of Alabaster. This is the direction of Glacial motion. Hence it is not surprising to find gypsum disseminated through the drift. Prof. C. A. Davis has called attention to a bowlder of gypsum as large as two fists, which he discovered near Alma. This is certainly exceptional, and is of interest as showing the recent date of ice movement. A certain amount of gypsum is disseminated through the drift in this region and gets into the water. This is most marked at Mount Pleasant and in the region immediately around, as at Leaton. Here the wells in the drift, whether deep or shallow, are, without exception, permanently hard and highly impregnated with sulphate of lime. These mineral waters, though free from bacterial contamination and not likely to produce typhoid and diphtheria, are said to be injurious to the bowels and bladder of certain constitutions, while they might be what others need. Persons in this region who tend to a uric acid diathesis might find filtered rain water better than patent medicines. A trace of common salt, or lithium carbonate or sodic sulphate, might be added to remove the flat taste of the water.

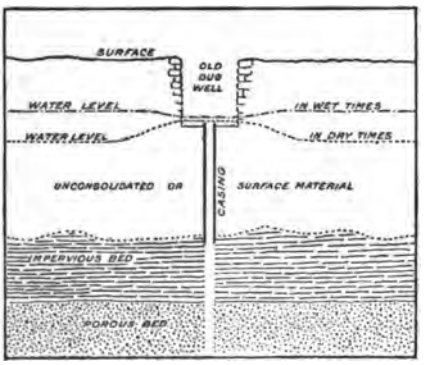


FIG. 9.—Diagram illustrating evils of insufficient casing.

This district is much like the first except that gas is not common in the wells. The wells in surface sands are usually shallow and easily exhausted in dry times. Deeper wells in quicksand or gravel in or under the clay can generally be obtained, but the water is often very

hard. The thickness of drift—i. e., depth to bed rock—is quite irregular, but is much greater to the northwest.

One practice common in this district but not confined to it, which can not be too strongly deprecated, is drilling from a basin or dug well and letting the water resulting flow directly into the basin, the upper basin remaining as pervious as ever. The way in which this practice arises is simple and natural. A farmer begins by a dug well, perhaps 16 feet down in the surface sands, as in fig. 9. In a dry season like that of 1895 his well goes dry. He borrows an augur and bores down through sand and then through the clay, say 20 feet more, and strikes another porous bed full of water under a good head, which rises and fills his well up far enough, and he stops satisfied. But in the first place the impervious clays through which he has bored will probably creep in and fill the hole, and in a few years the work will have to be repeated. In the second place, suppose that the well is cased from the bottom, or that the flow from the lower pervious beds is so strong as to keep the hole open; in dry times the water from the lower bed will still work out sidewise through the stone curbing into the upper beds that have gone dry. Thus the head of the lower beds will be wasted, and some neighbor who has had a flowing well from that bed may suddenly find his flow stopped, while he himself will have to exert himself more than should be necessary in operating the pump. Again, if there is a strong flow upward from the lower beds, sand may be carried up in sufficient quantities to fill the upper well and leave a cavity around the bottom of the hole through the impervious beds, into which they will finally fall and seal the well, even though the beds themselves are cased. Finally, there is nothing to prevent a rainy season from reversing the process—raising the water level in the upper beds, changing the current, and contaminating the supply with rain water and surface drainage, so that the certainty of purity, which might easily be obtained, is lost.

If, however, as shown by the dotted lines, the hole is cased and the casing continued to the surface, the head of the lower bed will be preserved, risk of contamination removed, and the life of the well lengthened.

NORTHEASTERN SHORE DISTRICT.

This district is occupied mainly by the drainage valley of Thunder Bay River, with the lower reaches of the streams which drain into Huron Bay between it and the Tittabawassee, and the streams, mostly small and insignificant, which lie to the north of Thunder Bay River.

To the southwest of this district lies the high interior moraine which surrounds the Muskegon, marks most sharply the outline of the Michigan-Saginaw cusp, and probably includes the highest points of the peninsula (e. g., 1,465 feet, at Jim Cook's knob, on the north line of sec. 34, T. 24 N., R. 2 E., and, it is said, 1,682 feet near Otsego). Near West Branch the district approaches nearest the waters of the

lake, and there and at Wolverine the descent, from over 1,200 feet to less than 700 feet, is very abrupt, especially in the stream valleys. This region is but newly settled and is still in large part wilderness.

The general character of the district is somewhat as follows: Around the nucleus (the central district) of sand plains, about 1,180 feet above tide, except as cut by river valleys, runs a moraine, which is mainly or at times entirely covered with sand and frequently rises over 1,400 feet above tide. (See fig. 8.) There is also another sand plain, about as high as the inner sand plain but narrower, and then a moraine, only about 1,200 feet above tide, which is clayey and clothed with hard wood, especially on its northerly or easterly side. Then the moraine is deeply gullied, and there is a rapid drop to about 960 feet above tide, where there are again extensive sand plains. Inclosing these is another broken clayey morainal belt frequently 1,000 feet above tide, and then another drop brings us to about 800 feet above tide. Below this the moraines are less marked, and gravel ridges, produced as shore beaches, replace the extensive overwash sand plains of the higher regions, studded with jack pine. The soil becomes clay with streaks of sand, rather than sand interrupted by lines of clay hills. In other words, there is a series of encircling moraines as shown on Pl. II, and between each moraine and the one next within the valley the space has been filled with sand, shown in brown and crosshatched, nearly to the level of the outer moraine, and often covering it heavily. In the sandy regions water may be obtained from surface sand, though it may be quite deep. Whenever streams like the Au Sable or Au Gres have cut down through the sands to underlying clays springs occur, and they are abundant in this region.

The drift through all this region is probably deep, and the clay moraines probably mark epochs of readvance of the ice, when it was likely to override the sand deposits formed in front of it in its retreat. In the few deep wells already sunk deposits of sand and gravel are found under the clay and till. Wells sunk into them, especially near the moraine belts on the north and east sides, may be expected to find plenty of water with considerable head. Fig. 8, from conditions at Rose City, will show how favorable are the conditions for artesian wells. There are high, sandy gathering grounds on the side south or west of the moraine, and higher semi-impervious ground with higher water level between the gathering ground and the discharge.[1] Flowing wells may be expected, therefore, all along from West Branch past Rose City to Indian River.

On the moraine belts the same sheets of water-bearing gravel may be struck, but the height to which the water will rise in the well depends on the altitude.

On the sand plains to the southwest of a moraine belt it will be necessary, except in low spots, to go deep for even surface water. There

[1] Requisite and qualifying conditions of artesian wells, by T. C. Chamberlin: Fifth Ann. Rept. U. S. Geol. Survey, 1885, pp. 131 to 172.

are a great many fine, undeveloped water powers in this region, and lakes are quite numerous. The quality of the water is generally excellent. It is, of course, hard, and it has been stated that 80 per cent of horse diseases are due to hard water. The water is not suited to boiler use. But the hard water of this region probably differs from that of Saginaw Valley and around Mount Pleasant, in that its hardness is largely temporary, as letting the water stand removes some, and boiling or breaking with quicklime all, of the hardness, which consists of lime and iron.

On the other side of Thunder Bay River a smooth moraine, which covers an underlying limestone ridge, gently rises. The coating of drift is shallow, the underlying limestones are pervious, and it is often necessary to go down into rock to obtain a permanent water supply.

Throughout this district there are many ponds. In some the water is said to be quite soft. The ponds are either clay moraine tarns, crooked lakes left in abandoned channels of the old ice drainage, or sometimes sink holes and valleys in the limestone. At present their main worth is to the hunter, the fisherman, and the lumberman, but the time may come when they will be useful as reservoirs for mill streams or as town water supplies. In most of this district good water supplies can also be obtained from the rock, though at considerable depths.

WESTERN SHORE DISTRICT.

There is much greater difficulty in defining, by natural characteristics, this district than some of the previous ones. There is a series of moraines which come diagonally down toward Lake Michigan (see Pl. V), becoming gradually lower, more extended, and more undulating in contour. The moraines are heavily swathed in gravels, sands, and clays of the valley trains which lie between them. At the extreme north of this district, from Bay View and Petoskey southwest, there is a rock ridge, and there is probably also a rock ridge from Grand Rapids northwest into Oceana County, where the drift covering is comparatively thin. Between these ridges the drift is very thick, so that only the deep salt or mineral wells strike rock, which is encountered 500 or 600 feet down. Probably the relief of the rock surface is considerable. This thick layer of drift is generally varied in section, as the wells at Big Rapids, Traverse City, etc., show, and various sands and gravels yield water; and on lower grounds, as at Traverse City, at the Nochemo springs (really wells), near Reed City, around Empire and White Cloud, and at Mecosta, flows are likely to occur. The level of the flows at these places is below that in the adjacent country, but on the higher grounds, as about Walton, especially on the great sand and gravel plains which are so pronounced a feature, it is often necessary to go 100 feet or more to reach water. Usually, however, water can be reached by a drive well, and of course water at such depths is steadier in supply and freer from some forms of contamination.

The deeper a surface-water well is the farther it should be away from any privy.

At the extreme north, north of Harbor Springs, there is a singular district, which seems to have an exceedingly heavy coating of drift and overwash gravel and which is so porous that wells must be sunk 300 or 400 feet to water.

Toward the south in this district there is a region of shallower wells and drift, but the varied character of the drift continues. Occasionally a section will be found which shows no pervious bed; this may be expected mainly along the moraines, indicated in Pl. II. Usually, however, even in the belts marked as moraine ridges, sufficient minor alternations in the drift exist.

The relatively greater thickness of drift, and the ample supply of water which may be obtained from the Glacial drainage gravel deposits, account for the relative scarcity of strongly mineralized waters in the area of the coal measures and Michigan series compared with those in Saginaw Valley.

NORTH CENTRAL DISTRICT.

This district includes the upper valleys of Manistee, Muskegon, and Au Sable rivers, and is bounded by the northeast district and the west district, previously described, or, in a general way, by the second of the series of ascending moraines, which passes through Lewiston. On the south it may conveniently be brought down to the second correction line of the Land Office, or about to the Ann Arbor Railroad. As thus defined, the district is characteristically sandy. The depth of drift is probably often very great, how great is not known, as no wells have reached rock.

Wells are generally driven, not drilled, and water may be from 17 to 60, 80, or even 180 feet through the sand, depending on the altitude. The first encircling moraine appears to be as sandy as the intervening plains, though the sand may mask clay. On the lower parts of the plains, as at Roscommon, there is but 12 to 14 feet of sand above clay, and below this clay are sheets of water which flow, or at least have good heads. The water is said to be comparatively soft, but it is by no means equal to rain water.

SAGINAW MORAINE DISTRICT.

This central part of the State lies higher than the old lake bottoms of Saginaw Valley and the eastern shore, and is more varied in its topography. It is generally undulating, with 20 to 30 foot rolls, and occasionally rises to hills 100 to 200 feet high. While, as a whole, it lies on a rock ridge—largely the Marshall sandstones—the rock surface does not at all conform to the minor undulations of the present surface. Consequently the depth of the drift varies, occasionally exceeding 200 feet but being more usually 30 to 50 feet. Over these areas there is a great variety in the drift deposits.

BARRIER BEACH CONNECTING EMPIRE BLUFFS AND SLEEPING BEAR POINT, LAKE MICHIGAN.

While in the eastern shore district the drift is almost uniformly clay or bowlder clay, here there are alternations of sand and gravel with till (hardpan), sometimes many of them, indicating retreats and readvances of the ice. The axis of the Thumb lies in this district, and it is traversed by many Glacial drainage channels with heavy valley trains, which yield abundant surface water.

Consequently, much less can be said about this district as a whole than about some others. Usually water is found above the rock, but as the rock waters are good and ample there are also numerous deep rock wells. Frequently the streams have cut down through the overlying sand or gravel to clay beneath, and in these cases springs are certain to appear. Occasionally erosion has reached bed rock. Not infrequently on the lower lands flowing wells, as well as springs, may be obtained, and they are found scattered all over the area; but on the higher lands and moraine ridges it is necessary to bore deep for water. Along the margin of this district, however, there is a sudden drop of the country, and along this belt wells are very likely to occur with flow ample enough in many cases, as at Rochester, for town supply. The quality of the water is almost invariably good—hard but not otherwise strongly mineralized.

SOUTH CENTRAL DISTRICT.

The conditions here are practically as in the Saginaw moraine district. The coating of drift over the sandstones in the valleys is usually thin, while beneath the hills it is 100 feet or more thick. Between the hills are usually swamps and Glacial drainage deposits or valley trains. In some places in Hillsdale County the drift is found to fill and obliterate pre-Glacial channels. One of these lies about 5 miles northwest of Jonesville; and another, which traverses the county from east to west, passing near Osseo, has been described by Mr. H. P. Parmelee in a paper read before the American Association for the Advancement of Science, but not published.

DEEPER WELLS AND PALEOZOIC STRATIGRAPHY.

Below the mantle of sands, gravels, clays, and till which we have considered in the last section, the drill encounters the consolidated rocks of the Paleozoic series. Among the rocks the drillers readily distinguish the black, white, blue, red, and sandy shales, the white or brown sandstones, and the harder limestones. Soap rock or soapstone is usually very clayey, and is often a calcareous shale. Between limestone and dolomite no distinction is made, although the latter is sometimes mistaken for sandstone. The last two, especially when full of chert nodules, "flint" layers, etc., are usually much more difficult to drill than sandstones and shales. Sometimes a ball of pyrite or a nodule of sideritic iron ore will resist the drill as effectually as flint, and may pass for such. The variation in hardness naturally

makes a great difference in the cost of drilling. While for 2-inch holes in the softer strata (the coal measures or Coldwater shales) 50 cents a foot has been a standard rate and will yield good wages if there is no special difficulty encountered, some specially hard layer of a foot may take more time than all the rest of the well; and in general through the State wells have cost about $1 a foot. Usually half the time at least in drilling a well is consumed in overcoming exceptional difficulties and in making repairs.

In mere churn drillings coal is difficult to distinguish from black shale, at least to determine its exact thickness; though an expert, by turning the drill 90 degrees each time and thus getting larger pieces, and by noting especially the peculiar crunch under the drill, which may be felt if the hand is on the rope, may ascertain approximately the nature and thickness of a deposit. Gypsum or plaster is another substance which is often not recognized, and which it is highly important to avoid if good drinking water is desired.

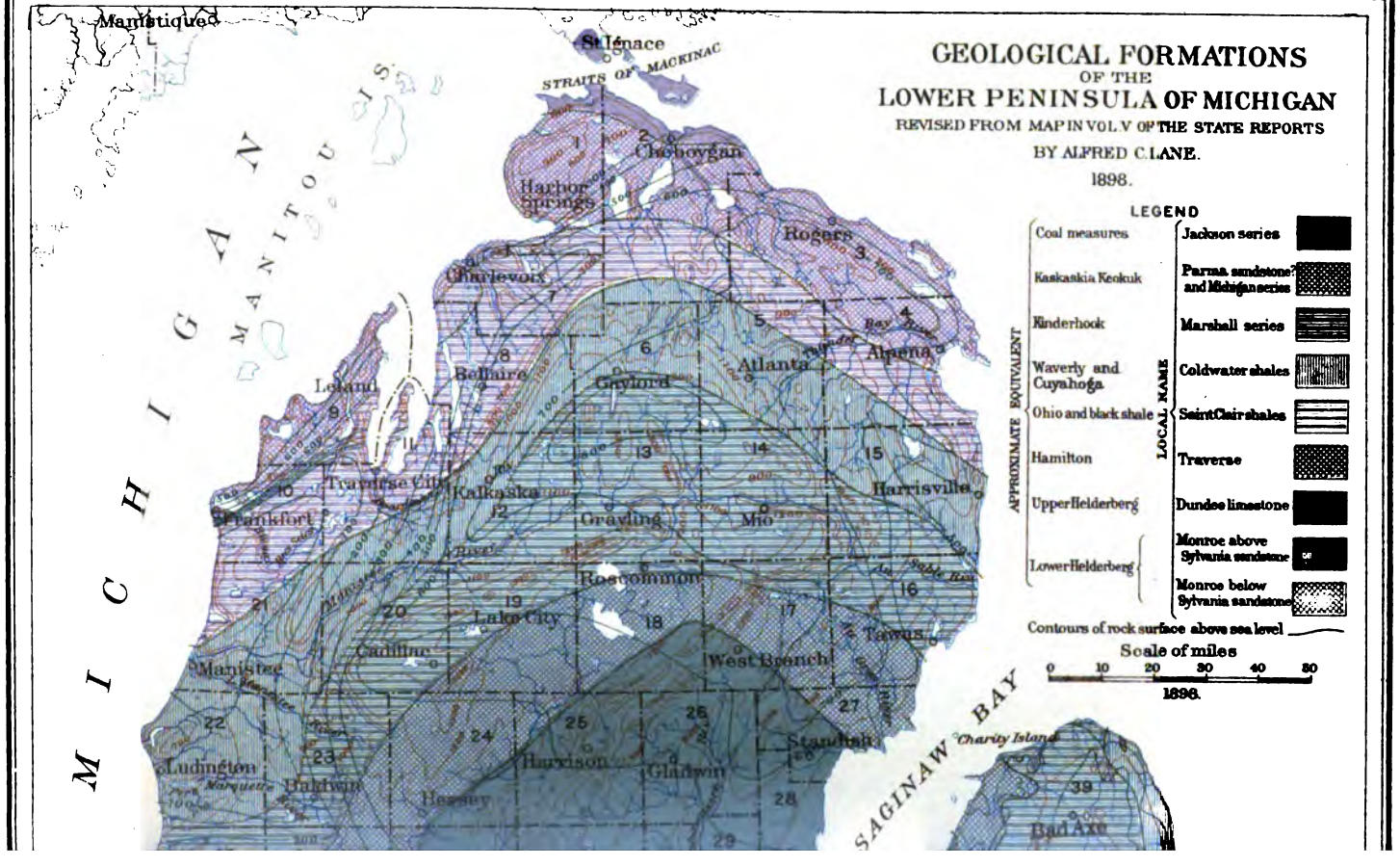
Usually, just before striking through shale into a strong stream of water with a good head, a certain springiness of the churn drill is noticed by the driller, which warns him that some new development may soon be expected, and it is common to find a red layer or a hard cap (specially charged with pyrite) or crust just before piercing a stratum containing salt water. Is not the sulphur of the ferrous sulphide of the hard cap, or the ferric oxide of the red shales derived from the sulphates of the brine?

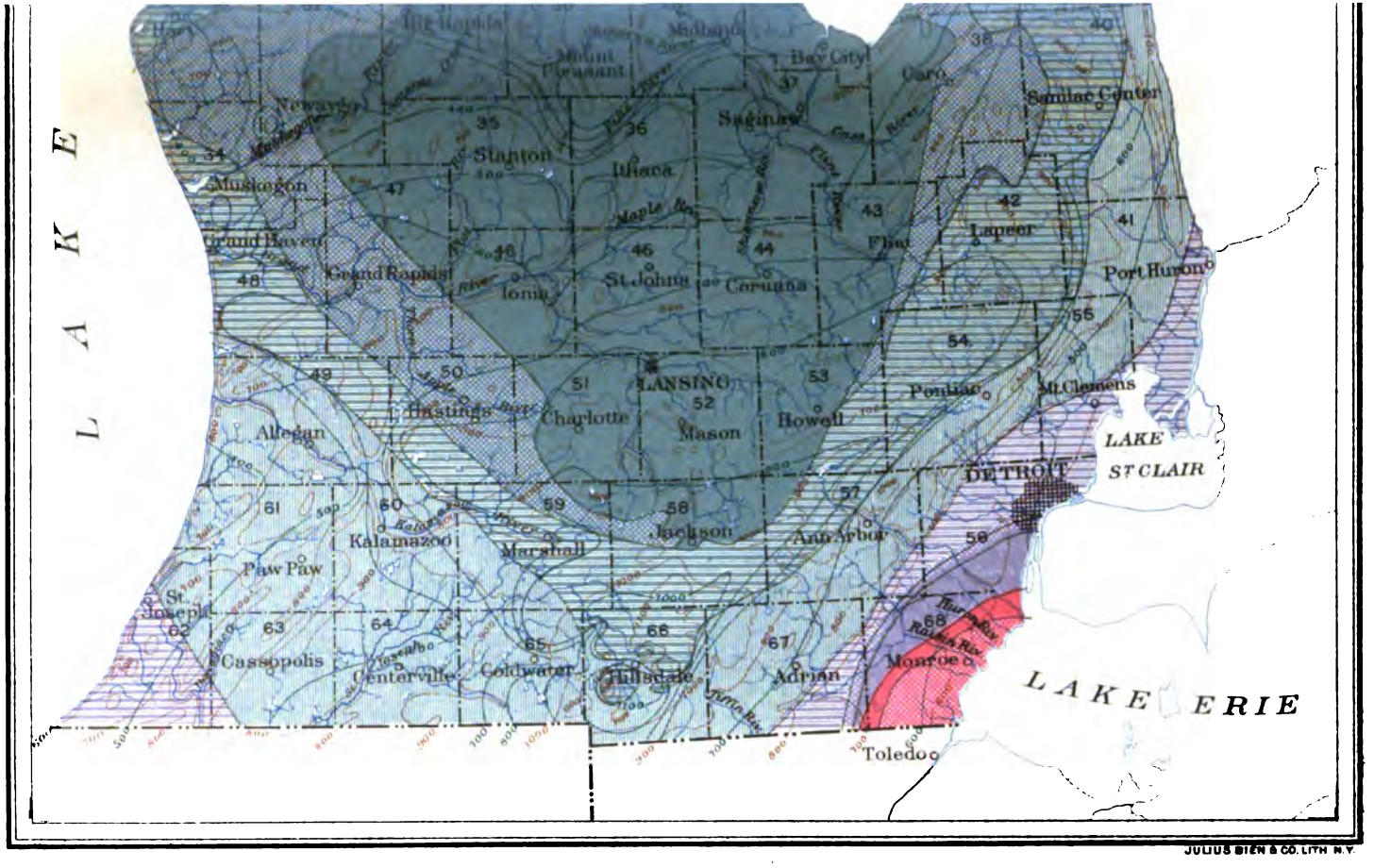
A description of the rock series, not primarily from the view of the paleontologist or general geologist but from that of the seeker after water—fresh, medicinal, or salt—follows.

CARBONIFEROUS FORMATION.

JACKSON COAL MEASURES TO MARSHALL SANDSTONE.

The central part of the State, as shown by the map, Pl. VI, and by the cross section, fig. 10, is occupied by a series of rocks belonging to the Carboniferous formation, in some respects not unlike the coal measures of Ohio and Indiana, with some beds that can be closely paralleled with those coal measures and yet with such marked points of difference as to render it probable that for most of the time, at any rate, there was little or no continuous connection with any other State, but that the rocks were laid down in an inland sea, between Canadian highlands on the north and flat reaches of the emerging continent on the south. At the base of the series is a heavy white sandstone—the Napoleon or Upper Marshall—which is very massive and thick to the east and southeast, as shown in fig. 12, but becomes somewhat thinner toward the north, although it is rarely less than 50 feet of well-defined water-bearing sandstone. It lies directly under the drift, as the map shows, through most of the broad belt of higher land that extends from the Thumb down to Hillsdale County. It is a


GEOLOGICAL FORMATIONS
OF THE
LOWER PENINSULA OF MICHIGAN
REVISED FROM MAP IN VOL V OF THE STATE REPORTS
BY ALFRED C. LANE.
1898.
LEGEND
APPROXIMATE EQUIVALENT
Coal measures
Kaskaskia Kaskuk
Kinderhook
Waverly and Cuyahoga
Ohio and black shale
Hamilton
Upper Helderberg
Lower Helderberg
LOCAL NAME
Jackson series
Parma sandstone and Michigan series
Marshall series
Coldwater shales
Saint Clair shales
Traverse
Dundee limestone
Monroe above Sylvania sandstone
Monroe below Sylvania sandstone
Contours of rock surface above sea level
Scale of miles
0 10 20 30 40 50
1898.
MICHIGAN
MANITOU IS.
Manistique
St Ignace
STRAITS OF MACKINAC
Cheboygan
Harbor Springs
Rogers
Charlevoix
Atlanta
Alpena
Leland
Bellaire
Gaylord
Traverse City
Kalkaska
Grayling
Mio
Harrisville
Frankfort
Roscommon
Lake City
Tawas
Cadillac
West Branch
Manistee
Standish
Ludington
Baldwin
Harrison
Gladwin
Hersey
Charity Island
Bad Axe
SAGINAW BAY


LAKE
LAKE ST CLAIR
LAKE ERIE
Hart
Big Rapids
Mount Pleasant
Midland
Bay City
Caro
Sanilac Center
Newaygo
Muskegon
Stanton
Ithaca
Saginaw
Grand Haven
Grand Rapids
Ionia
St Johns
Corunna
Flint
Lapeer
Port Huron
LANSING
Hastings
Charlotte
Mason
Howell
Pontiac
Mt Clemens
Allegan
DETROIT
Kalamazoo
Marshall
Jackson
Ann Arbor
Paw Paw
St Joseph
Cassopolis
Centerville
Coldwater
Hillsdale
Adrian
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Toledo
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JULIUS BIEN & CO. LITH N.Y.

prolific water bearer, yielding numerous flowing wells at a moderate depth (250 feet) throughout the west part of Huron County to Sebewaing. Under Tuscola county it continues, as at Fairgrove, though at Reese it is getting a little too salt, and so along past Flint, Vassar, and Birch Run, to Corunna, Lansing, and Mason. Along this line and south there is usually good water in this formation. There is frequently above this formation intensely salt or bitter waters, pierced on the way going down, which must be cased out. It seems that to the northwest an arm of the sea was cut off from the ocean, where evaporation exceeded precipitation, depositing the gypsum beds which extend from Alabaster and Soule, in Huron County, to Grand Rapids, and saturating the rocks with a very salt brine. This formation has no parallel in adjacent States, and hence is known as the Michigan series. It consists of light-

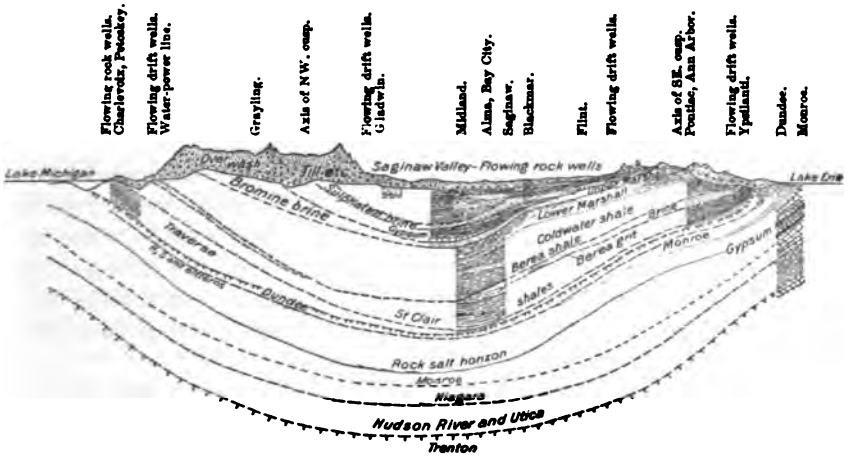


FIG. 10.—Cross section of the Lower Michigan Basin. Horizontal scale, 1 mile = .135 inch; vertical scale, 1,200 feet = .321 inch.

colored blue or gray shales, hydraulic limestones, and gypsum beds Its extent to the southeast seems to be somewhat irregular, as it lies in bays and synclinals in the Marshall sandstone. It can be followed, even where it does not outcrop, by its effect on the mineral waters.

In fact, in many parts of Lower Michigan, where outcrops of bed rock are scarce, important geologic data can thus be gathered. In much of our work in Huron County, Professor Davis and I discarded the familiar tools of the geologist, the hammer and the compass, and instead carried a urinometer and a small leather case containing barium chloride ($BaCl_2$), for sulphate test, silver nitrate ($AgNO_3$), for chlorine test, ammonium oxalate—$(NH_4)_2C_2O_4$—for lime, and sometimes tannic acid, for iron, and went from farm to farm inquiring the depth to rock, etc., and testing the waters. The line between the Upper Marshall or Napoleon and the Michigan series was traceable, sharply within a mile, by the reaction for sulphates which the latter series gave, and by a rapid increase in total mineral contents. This

purely objective line agreed with reports as to the nature of the rocks and the rare outcrops. (Compare Pl. VI and fig. 12.) For further details reference may be made to the forthcoming report of the State geological survey on Huron County.

It is not uncommon, however, to find good fresh water in the Marshall sandstones directly beneath the Michigan series; there seem to be two reasons why the salt water has not worked down and charged the Marshall sandstone.

In the first place, as the Marshall sandstone outcrops all around under the high land, there is a strong pressure, nearly if not quite enough to make the water in the center of the basins rise to the surface. Thus the tendency is for the water to work up rather than down in the lower central parts of the Michigan Basin, which are overlain by the Michigan series and by the outcrops. This tendency has been shown in hundreds of wells for fresh water and in dozens of wells for brine, which have been put down in the Saginaw Valley. The Marshall, toward the center, becomes deeper and more salt. It is the source of the brines of Saginaw and Bay City, of the brominiferous brine of Midland, St. Louis, and Alma, and probably of that of Big Rapids; it is almost saturated with salt. The salt, however, is not derived from above, since it is comparatively free from gypsum. At one time the wells in the Saginaw Valley made a really noticeable reduction in the percentage of salt contained in the brine. They may have drawn in fresh water from the sides to replace the brine extracted at the middle of the basin. The Marshall sandstone is generally easy drilling.

The overlying Michigan series from Bay Port to Saginaw, Midland, Alma, and Grand Rapids is a trifle over 200 feet thick. The position and thickness of the gypsum and hydraulic limestone beds, which are intercalated in the prevalent series of gray or blue shales, are not constant. To a certain extent this appearance may be due merely to imperfect records. Some of the gypsum beds are quite extensive. To the southeast, even around Sebewaing, the gypsum feathers out. Of its character to the north little or nothing is known. Water from the Michigan series is generally scanty or strongly mineralized. Occasionally pyritiferous beds and cherty limestones make hard drilling.

A change of climate, or more likely a slight depression making an open sea, probably caused the deposition on top of the Michigan series of a series of cherty limestones and sandstones of an entirely different character from those of the Michigan series—almost exactly paralleled by the Maxville limestone of Ohio and rich in similar fossils. In this series I am now inclined to include not only the Grand Rapids limestone but Winchell's Parma sandstone. The sections and borings at Bay Port, at Charity Island, and elsewhere have convinced me that limestones and sandstones are intimately intercalated at this horizon. Many of the sandstones are highly cross bedded, and according to the observations of the writer are apparently mere sand

bars. This is noted in the drill cores of the Bay Port quarry explorations by Rominger, who called it an unconformity, also on Charity Island, and by Winchell in his original description of the Parma around Jackson. The Bay Port limestone has the strongest possible resemblance to the Grand Rapids limestone in character and in fossils, and both are intimately associated with and underlain by sandstones.

The brines of this horizon, as pointed out by Garrigues, run higher in sulphates of lime, etc., and lower in earthy chlorides than do those of the Marshall; this is in harmony with the general theory of the upward pressure of the waters of the basin. The Parma sandstone is not always recognizable as distinct from the Marshall, although to the north from Bay Port it can be fairly well traced to Sebewaing, Bay City, Midland, Alma, and as far as Ithaca to the southeast toward Corunna and Flint. As the Michigan series feathers out this Parma sandstone either feathers out also or merges in the great shore development of the Marshall sandstone. (See fig. 10.) I now think that the record of the Jackson well is misinterpreted.[1] The Parma and Marshall are both probably merged in the great sandstone from 83 to 373 feet below the surface, the dividing line being perhaps near 200 feet, while the blue sandstones at 415 and 660 feet are probably merely minor beds of the Lower Marshall or Coldwater, respectively—Cuyahoga formations, especially as they are not free water bearers.

Returning once more to the Parma horizon—that of the Grand Rapids and Bay Port limestones—the water is usually hard, but at Bay Port it is quite pure, and no doubt is the water horizon of many wells besides those at Ithaca, especially in the region about Mason, Lansing, Owosso, and Birch Run, where thus far it can hardly be separated from the Marshall. It has been but little used for brine.

Above the Parma comes a varied series of black shales, fire clays, black band iron ores, and coals and sandstones. The sandstones usually yield water, but the water is generally quite mineralized (being occasionally prescribed for the sick) and is sometimes a brackish water which cattle drink greedily. Wells in the coal measures generally have a good head, and frequently flow. The sandstones are generally white, except well up in the series, while to the northwest, around Ionia, Ashley, St. Johns, St. Louis, and in Garfield Township (T. 16 N., R. 3 E.) there are records of a red sandstone, which Winchell called the Woodville sandstone. This red sandstone also yields water which is rather strongly mineralized, but it is yet little known, and it can not be said how far the red color is due to surface oxidation. In some cases it appears too thick for that and reminds one of the upper barren coal measures of Ohio and West Virginia, and, as at Saginaw, it appears to be quite unconformable on the coal measures proper.

[1] Geol. Survey Michigan, Vol. V, Part II, 1895, Pl. XXIII.

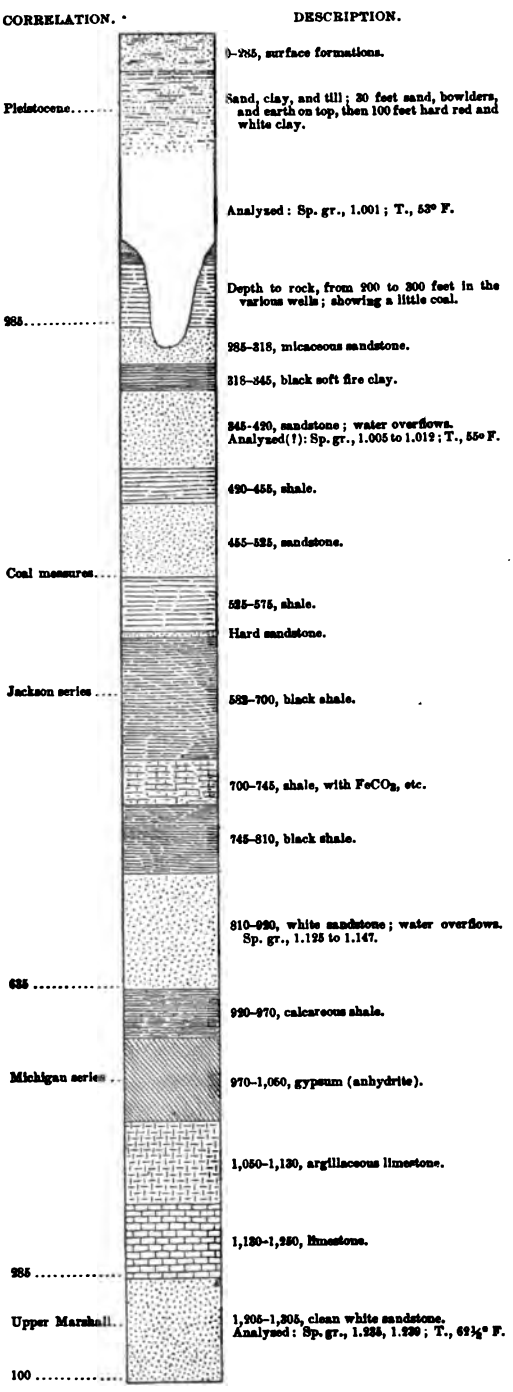


FIG. 11.—Section of well at Midland, Michigan. Altitude about 613 feet.

Above the Parma at Midland (see fig. 11), or combining the well records at St. Louis and Alma, there is a series of coal measures 400 to 600 feet thick, and sandstones are very abundant in the upper half, but are also very irregular—mere channels which will here cut entirely through a coal seam which a few feet away will be as strong as ever. One bore hole has found no coal, and 30 feet away one put down later for water passed through 3 feet of coal. These sandstone channels have been excellently exhibited in some of the Jackson coal mine plans by J. Holcroft.

This coal basin was deeply cut into by stream valleys before the ice swept over it and filled them. Hence the depth to rock is very uncertain and is more uncertain toward the northwest. The shore ridge of Marshall sandstone seems to have acted as a divide from which the streams flowed, gathering strength as they went. The abundance of deep wells in Huron County has rendered it possible to trace quite accurately in the rock contours of Pl. VI one valley which, coming down from Soule, is deflected by the Bay Port limestone and passes south through T. 16 N., R. 10 E., being about 140 feet deep, while on the general plateau

around the valley the depth of drift is less than 50 feet. Thence it passes 3 miles southeast of Sebewaing, then close to Unionville, and on west. There are irregularities in the depth of wells around West Saginaw and Bay City that indicate spurs of this valley, and the next well-marked location is at Midland, where some wells, like those near Hubbard to the north, find only about 200 feet of drift, while others, at the east end of the town, find 300 feet of drift. Wells are said to have struck rock at 76 feet in Mount Pleasant, but on the other hand wells north of there have gone 160 feet, wells west 355 feet, and wells south 205 feet without striking rock. At Alma it is 495 feet to rock, and at St. Louis, 3 miles away, it is only 355 feet or less, and at Ithaca 330 feet. At Big Rapids it is 600 feet to rock, while at Ludington, Manistee, and Frankfort, although close to the lake, there is a great depth of drift. These facts indicate clearly enough an incised valley system of 100-foot ravines, and also seem to indicate, contrary to Spencer's very natural hypothesis, followed by Mudge,[1] that the drainage of the coal basin was toward the west and not by Saginaw Bay, both because the depth of the ravine steadily increases, and also because the limestone ridge seems to run continuously across the mouth of Saginaw Bay, from the islands off Bay Port, in continuous rock bottom to Charity Island, and outcrops again on the north shore. The limestone may be followed near Omer and Prescott at a higher level than the bottom of the valley just described. The rock contours of Pl. VI illustrate these facts.

The troughs which Mr. Mudge assumes represent troughs or valleys in the rock surface are sufficiently explained by the Glacial drainage, which, indeed, Mr. Mudge has pointed out for the Ionia channel; and the very fact that in the Ionia channel the Grand River has in two distinct places struck bed rock far above the lower rock surface of the Saginaw Valley makes the supposition that it follows a rock channel rather forced. There are two other arguments of a general nature for my interpretation of the rock surface. In the first place, the rock ridge seems much more broken, the depth of drift far more irregular, and the topographic relief greater in the Grand Traverse region than in the Thumb of Michigan, which indicates that the former region is farther downstream, or nearer the master valley, than the latter. In the second place, the generally accepted theory of a greater northern elevation of the land preceding glaciation disproves the supposition that the gradient from Alma northeast was reversed, and makes the course of the valley from Bad Axe to Ithaca even more natural. From that point on its course is much less certain. It seems to have been deflected when it met the northwest-striking sandstones and limestones beneath the softer coal measures, at the southwest side of the coal basin.

[1] Am. Jour. Sci., 4th ser., Vol. IV, 1897, p. 384.

CARBONIFEROUS AND DEVONIAN SHALES.

LOWER MARSHALL SANDSTONE.

Beneath the heavy Upper Marshall sandstone which, as has already been mentioned, lines the shore of Huron County from Rush Lake to Hat Point, there are in Huron County (see fig. 12) about 260 feet of strata which are largely sandy flags and include three well-marked sandstones, one outcropping at Port Austin, another at Pointe Aux Barques, and another—the famous Huron blue stones, used for whetstones and grindstones throughout the United States. The series is very ferruginous, and beds often become red and friable as the iron oxidizes, although they are green or blue when fresh. These sandstones may be traced under cover by wells or by scattered outcrops through Huron County and into Sanilac County. Generally the supply of water is ample, the quality excellent (although occasionally salty streaks occur in the Lower Marshall), and occasionally, as near Bad Axe and Port Austin, in exceptionally low ground there are flows. As the sandstones are traced to the west under cover, they are soon lost, except when they merge into a belt of red rock, paint rock, red shale, sandy shale, etc., in which form they may be traced quite continuously as far at least as Saginaw River. They are evidently shore deposits of no wide range and have not yet been successfully followed individually to the southwest. They are transition beds from the Upper Marshall or Napoleon sandstone to the great shale formation below. They are easy to drill, and extend the width of the Marshall belt, from which good water can be obtained a rather indefinite distance to the southeast.

COLDWATER SHALES.

Farther down, in the Coldwater shales proper, the sandstone seams grow thinner and finer grained, and the water contained is more apt to be salty. Little sheets of sandstone cemented by carbonate of iron, as at Pointe Aux Barques light-house, at Sand Beach, and at Richmondville, are found at various levels in the Coldwater shales, but in general this formation is composed of fine-grained, micaceous, bluish shales, easily drilled and very dry. In Caseville, about 400 feet below the Upper Marshall, is a brine which seems to be fairly persistent and which is possibly even more marked to the northwest. In outcrop balls of carbonate of iron are frequent, and one wonders how often the bands of limestone recorded as encountered in drilling are nothing but such balls.

BEREA SHALE AND GRIT.

About 1,000 feet below the Upper Marshall the shales become blacker. The horizon of the Berea shale recognized in Ohio is reached, and then all along the southeastern part of the State the Berea grit is

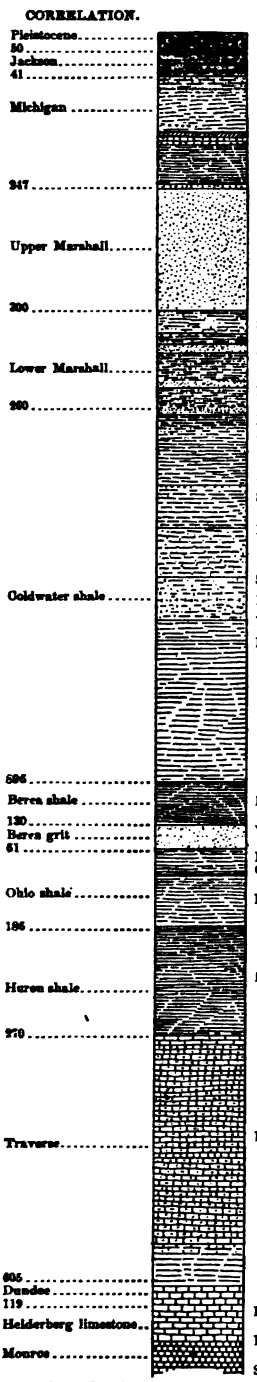


FIG. 12.—Geological column in Huron County, Michigan, adapted to the wells at Caseville and Sand Beach but illustrative also of those at Sebewaing, Bay Port, Port Crescent, Port Austin, Grindstone City, New River, Port Hope, White Rock, Forestville, etc.

well developed. It is a horizon well known for brine, and is followed to a depth of 1,650 to 1,750 feet at Caseville and at Blackmar, but is quite salt even when not very deep, as at Forestville, Ann Arbor, and Ypsilanti. At the latter place it seems to be more salt than underlying strata. It may be the source of some of the salt in wells about Ray (T. 4 N., R. 13 E.), Utica, Wales, and Rochester. With black shales above and below it is not surprising that the Berea grit frequently contains gas, and that many of the wells which strike gas immediately beneath the clays seem to be located over its beveled edge. It does not seem to be a marked topographic feature, nor does it break the general valley of the shales above and below. The Berea brines are of very good quality. Where recently struck in Bay City, at a depth of 2,200 feet, it actually flows, which, in a concentrated brine, indicates a considerable head.

ST. CLAIR BLACK SHALES.

Though the Bedford shales immediately below the Berea grit are often blue or red (oxidized blue), black soon becomes predominant, at

first in streaks (Cleveland shale), but later in a solid mass of 100 to 300 feet or more of bituminous shale nearly equivalent to the Ohio shale, a horizon widely marked and in a general way recognizable all over the State. This shale is somewhat sticky, but on the whole is easily drilled and is of importance as lying just above the horizons which contain most of the more famous bath waters of the State. From the Marshall down to the base of these black shales, with the possible exception of the Berea grit, there is no horizon of much importance either for brine or as a source of water, and in regions where these formations underlie the drift the prospects for rock wells for drinking water are not generally encouraging. Of course, near the outside margin good water may be obtained by drilling through to lower beds.

In general this great series of shales probably makes valleys lying between the Marshall sandstone ridge on one side and the ridge of the Dundee limestones on the other, and this is exhibited in the rock contours of Pl. VI and in the rock profile of fig. 10.

Very remarkable is the occurrence of a 6-foot bed of rock salt in this formation at Bay City, with black shale immediately above and below. This occurrence seems to show that the black shale is not a deep sea sargasso-like deposit.

LOWER DEVONIAN AND UPPER SILURIAN LIMESTONES.

TRAVERSE SERIES (HAMILTON).

A transition series between the black shales above and the limestone series below is of slight importance in the south part of the State, where it is about 80 feet thick, but rapidly increases in thickness and in interest toward the north. Along the St. Clair River—at Port Huron, and elsewhere—it has thickened to over 300 feet and is subdivided as follows:

Typical section of series between St. Clair black shales and Dundee limestones.

	Feet.
Hard argillaceous limestone	2
Shale, argillaceous soapstone	12
Limestones, "top limestones," argillaceous, often containing gas	80
Shale, "top soapstone," argillaceous	150
Limestone, "middle limestone," argillaceous	4
Shale, "lower soapstone"	65

Beneath the last member are light-colored Dundee limestones, yielding gas and mineral water. The "middle limestone" is not always recognized, and the shales are calcareous, so that they may be considered alternations of calcareous shales and of argillaceous marls or limestones. The division into a top of limestone and a bottom of shale can be traced throughout the State. On the north side of the basin, from Alpena to Charlevoix and Frankfort, the formation is 500

or 600 feet thick, retaining its marked shale base, and also the tendency to bluish, richly fossiliferous layers; but the formation is quite varied and dolomitic, as is seen from the Charlevoix and Petoskey records. (See fig. 13.)

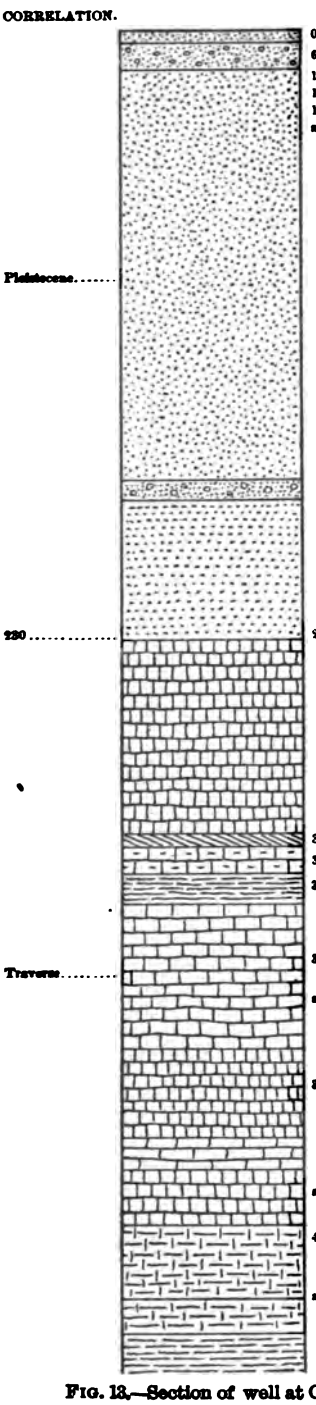


FIG. 13.—Section of well at Charlevoix, Michigan.

There are several streaks of limestone in this formation which yield more or less water, even in the southern part of the State, and to the north, as shown at Charlevoix, it is quite freely water bearing. There is some reason for thinking that the Alma well also is still in this formation, but the principal mineral-water horizon is just beneath.

DUNDEE LIMESTONE (UPPER HELDERBERG).

This formation has also been called the Corniferous or Mackinac limestone. Lithologically the upper limit of this formation is one of the best-marked lines that extends throughout the State. It separates a great series of bluish-gray or black clayey rocks from a great series of buff-yellow or almost white largely calcareous ones. It is

generally very light yellow in color, is full of flint, and is very hard, so that the drilling is slow at times. It effervesces very freely with acid, and some of the layers rank as the purest limestone of the State, containing 98 per cent of calcium carbonate ($CaCO_3$).

It is almost always more or less permeated with water which is charged with hydrogen sulphide (H_2S) even at Petoskey. When under greater cover the water becomes more salty, but is also strongly charged with other ingredients than salt—real bittern, or mother liquor—and is the most valued mineral water in Michigan.

The deposit of celestite with native sulphur has been associated by Professor Sherzer with the occurrence of traces of strontia (SrO) in these sulphureted waters. Frequently, also, oil or gas is encountered. In spite of the strength of this brine at times (at Charlotte the specific weight is 1.198) it is too impure for salt manufacture, and is mainly important medicinally.

The line between this formation and the one below, being one chiefly between limestone and dolomite, can be surely ascertained only by the use of acid. Hence over most of the State the line is still very uncertain.

THE MONROE AND SALINA BEDS (LOWER HELDERBERG).

These are the oldest beds exposed at the surface in the Lower Peninsula. Not more than 100 or 200 feet of these beds are exposed at the surface, but borings reveal over 1,200 feet, if with Orton we include in the group the salt beds (Salina). The beds are mainly buff dolomites and calcareous and argillaceous marls, associated with anhydrite and rock salt. Near the top a bed of the purest white quartz sand (often recrystallized), the Sylvania sandstone, extends persistently across Monroe County and can be traced under cover at least as far as Mount Clemens and St. Clair River. This sandstone is, of course, a good water bearer. Near Detroit, while at about 200 feet the strongly sulphureted waters of the Dundee are reached, at about 400 feet comparatively fresh potable water is met, and it seems as if it might be worth while to develop further this horizon, which is probably also encountered in Ypsilanti and Alpena. Below this sandstone the salt beds and brines of the Salina are reached. Rock salt is here in single layers often over 100 and even 200 feet thick; its aggregate thickness can not be estimated. These rock-salt beds extend apparently beneath (or at any rate skirt) the whole of the peninsula, from Alpena and St. Ignace down to a line drawn from Trenton to Muskegon. South of this line there is gypsum (or anhydrite), but not salt. A group of six wells at Trenton shows, within a few hundred yards, the exact margin of the salt basin.

This great thickness of salt suggests that there should have been a concentration, as at Stassfurt, in Germany, of the rare potash and bromine salts in the upper layers. The earlier Sand Beach analyses

indicated such concentration, but the water does not now give similar results. The Mount Clemens, Somerville Springs, and similar waters are clearly of the nature of mother liquors.

These salt beds, like all the beds, dip away from the St. Clair and Detroit rivers to the northwest, but after descending to depths of probably 3,000 to 4,000 feet, they rise again, and just north of the Straits of Mackinac gypsum beds outcrop. At St. Ignace a thin bed of salt is reported only 400 feet below the surface, while at Alpena rock salt is encountered within 1,000 or 1,200 feet. Though the Salina can not be sharply divided from the formation above or below, the following arrangement may be suggestive: at the top, dolomites and gypseous marl mark a time of desiccation; then comes an arenaceous dolomitic limestone passing into a glass sand—the Sylvania sandstone; then some more beds with gypsum and sometimes with rock salt; then 200 feet or more of somewhat gypsiferous dolomites; and beneath them a rapid succession of thick rock-salt beds, marking probably the first and greatest period of desiccation.

NIAGARA AND CLINTON FORMATIONS.

These formations have been struck only southeast in Monroe County, southwest from Kalamazoo, and north at Frankfort. The most characteristic part probably belongs to the Guelph formation—the churn-drill powder being almost white—a very fine-grained dolomitic limestone. It answers to Orton's description, and in accord with his remarks of the change from southern to northern Ohio, I recognize the Rochester[1] shale only at Wyandotte. Generally toward the bottom the limestone becomes more ferruginous and, as at Wyandotte and Dundee, a "red rock," and then the red shales of the Medina are reached. Concerning the water resources of this part of the column little is known. Water was noted at Dundee from these beds, but there is no report of its chemical character.

HUDSON RIVER AND UTICA SHALES.

There is next a great series of shales, struck only by a few wells in exploring to the Trenton, like those at Dundee, Monroe, and at South Bend, Indiana, viz: (1) The Medina red and green shales at Dundee, at a depth of 1,625 to 1,725 feet; (2) the Hudson River blue shales, about 300 or 400 feet thick; (3) the Utica brown or black bituminous shales, about 100 feet thick. This series is similar to the Lower Marshall, the Coldwater (Cuyahoga), and the St. Clair shale series.

[1] The Director of the United States Geological Survey has decided that hereafter in the publications of the Survey the term *Lockport limestone* will be used in place of the term "Niagara limestone," and the term *Rochester shale* in place of the term "Niagara shale," the word *Niagara* being reserved for the designation of some higher classific unit.—EDITOR.

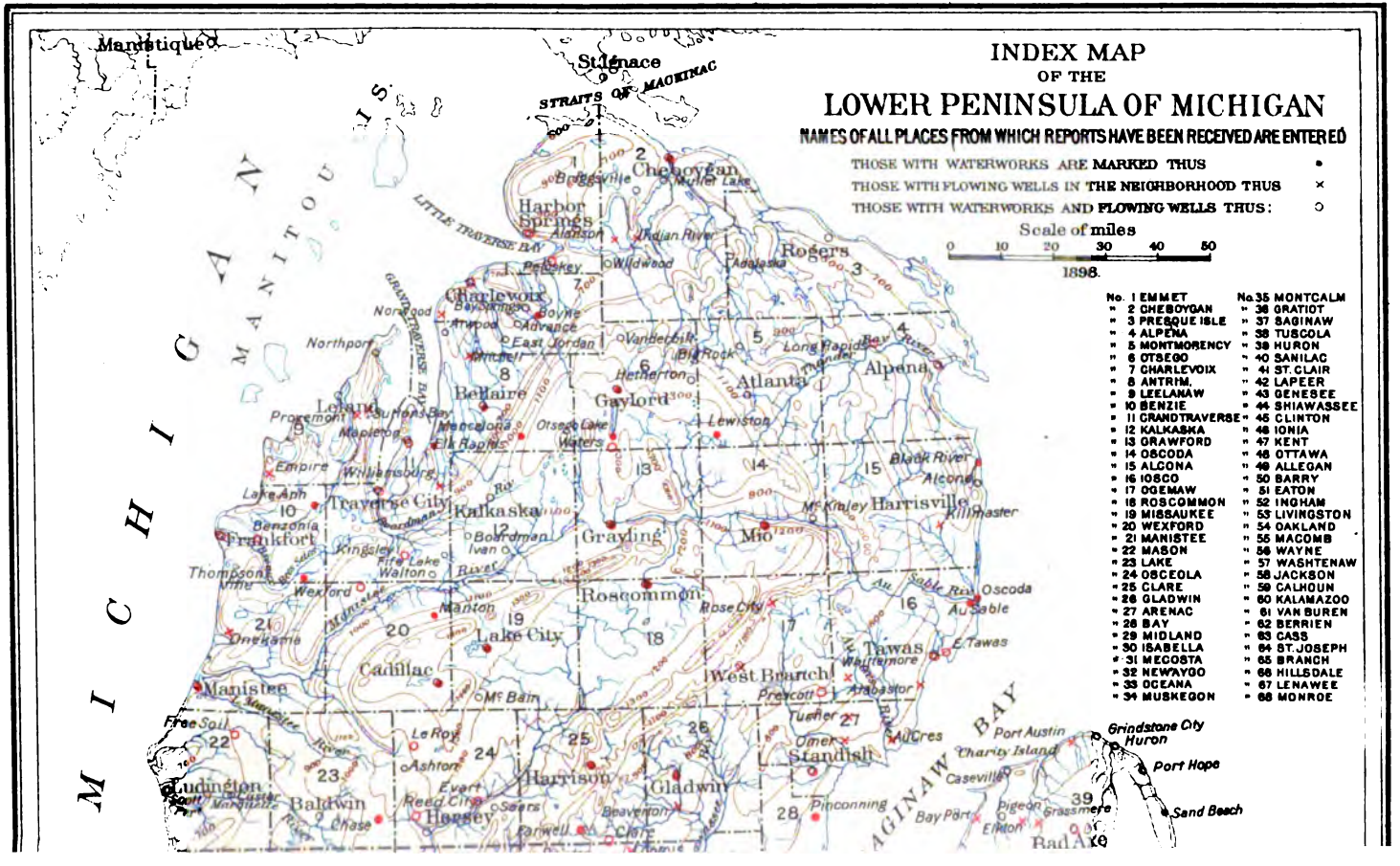
TRENTON LIMESTONE.

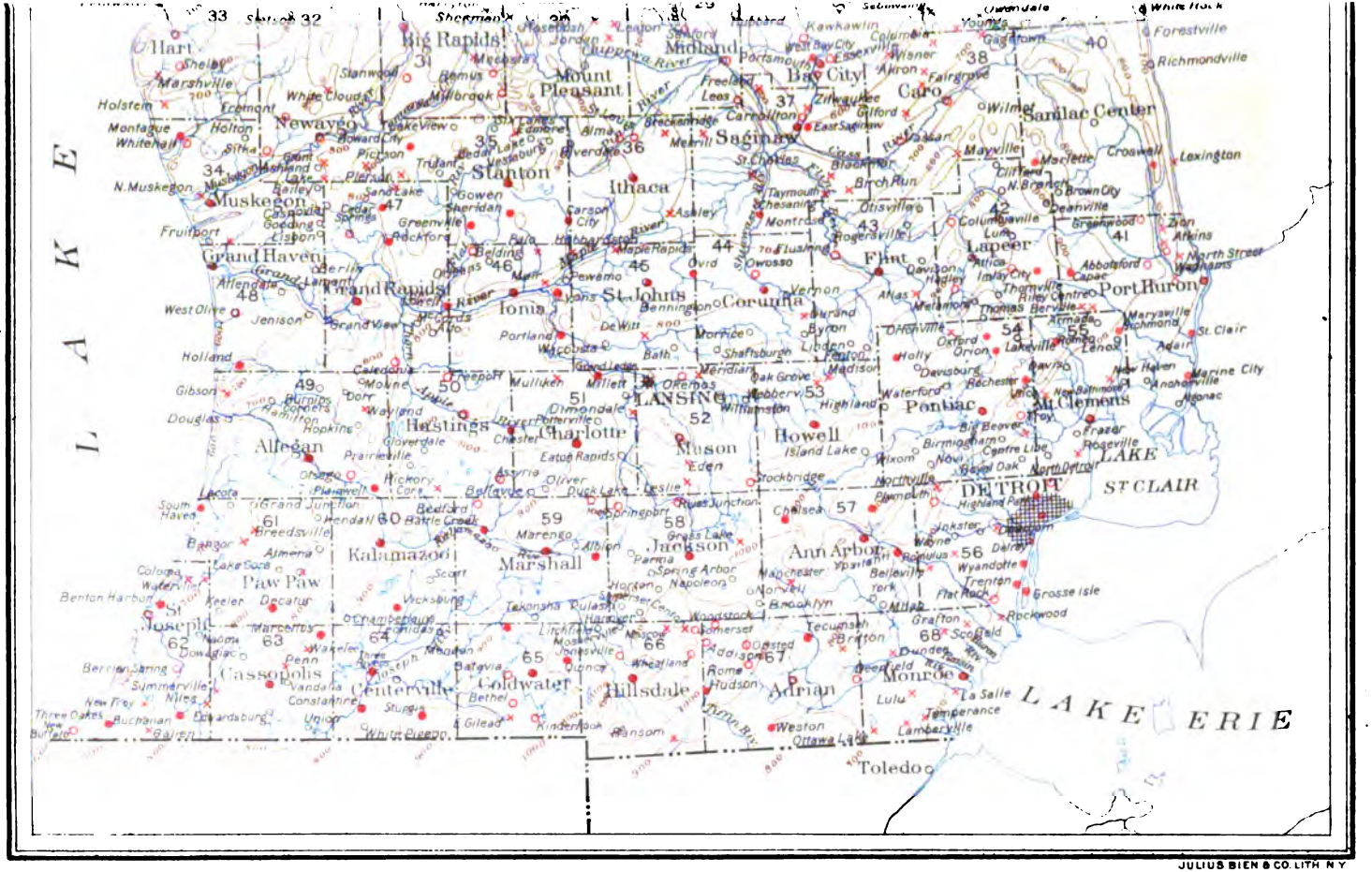
This formation has been penetrated a few feet at Monroe and at Wyandotte, somewhat further at Dundee, and again in the southwest part of the State, at Dowagiac. It is really a buff, granular, porous dolomite, with traces of gas and oil usually drowned out by a strong impure brine.

ROCK STRUCTURE AND TOPOGRAPHY.

The general structure of the rock basin, which has been described, is well shown by Pls. LXVII to LXX of Vol. V (1895), Pt. II, Michigan geological survey, which can, however, be improved by use of records since received; fig. 10 is a new section from Monroe to Charlevoix. The limestones and sandstones of the Traverse, Dundee, and Monroe make a rock ridge, which comes to the surface in Monroe County, can be distinctly traced as an escarpment, as Spencer has remarked, in the bottom of Lake Huron, and reaches land once more at Thunder Bay. From that point the ridge, though apparently broken beyond Cheboygan by cross valleys, continues nearly around to Frankfort, where the rock surface is slightly higher than at Manistee. The deep valley between this ridge and the Marshall sandstones is clearly defined in the well records in the southeastern part of the State, and seems to discharge near Algoma, where there is considerable thickness and where the depth to drift is irregular. This shale valley was overlooked on the northwest by an abrupt escarpment of Marshall sandstone, which is almost everywhere concealed, and yet within a mile the depth to rock may vary from less than 10 to 30, 40, or even 100 feet. This Marshall sandstone escarpment is more or less escalloped and ravined, as was indicated in Hillsdale County, and there are probably outlying areas or spurs of sandstone. On the main ridge of Marshall sandstone the rock floor is reported to be fairly level, and the irregularities in the drift are due to the irregularities of the moraine ridges, etc.; but in toward the coal basin, i. e., toward Mason County and around Pigeon, in Huron County, there is a system of valleys in the rock surface up to 100 feet deep. In the lower part of the Michigan series soft beds, easily cut, predominate, while the upper part, the Parma sandstone, the Bay Port limestone, etc., is more resistant, and shows an escarpment facing outward at least 10 or more feet vertically, and the valleys, as they traverse it, rapidly deepen to more than 100 feet. It is probable that some of the limestone masses which have so puzzled Winchell[1] and others have been outliers of this escarpment pushed or dragged off from the soft shales beneath and left stranded in the drift. They are particularly conspicuous, as Winchell remarks, in Oceana County, in the northwestward extension of the rock divide—which follows the Mar-

[1] Proc. Am. Assoc. Adv. Sci., 1875, p. 36.


INDEX MAP
OF THE
LOWER PENINSULA OF MICHIGAN
NAMES OF ALL PLACES FROM WHICH REPORTS HAVE BEEN RECEIVED ARE ENTERED
THOSE WITH WATERWORKS ARE MARKED THUS •
THOSE WITH FLOWING WELLS IN THE NEIGHBORHOOD THUS ×
THOSE WITH WATERWORKS AND FLOWING WELLS THUS: ○
Scale of miles
0 10 20 30 40 50
1898.
No. 1 EMMET
" 2 CHEBOYGAN
" 3 PRESQUE ISLE
" 4 ALPENA
" 5 MONTMORENCY
" 6 OTSEGO
" 7 CHARLEVOIX
" 8 ANTRIM.
" 9 LEELANAW
" 10 BENZIE
" 11 GRANDTRAVERSE
" 12 KALKASKA
" 13 GRAWFORD
" 14 OSCODA
" 15 ALCONA
" 16 IOSCO
" 17 OGEMAW
" 18 ROSCOMMON
" 19 MISSAUKEE
" 20 WEXFORD
" 21 MANISTEE
" 22 MASON
" 23 LAKE
" 24 OSCEOLA
" 25 CLARE
" 26 GLADWIN
" 27 ARENAC
" 28 BAY
" 29 MIDLAND
" 30 ISABELLA
" 31 MECOSTA
" 32 NEWAYGO
" 33 OCEANA
" 34 MUSKEGON
No. 35 MONTCALM
" 36 GRATIOT
" 37 SAGINAW
" 38 TUSCOLA
" 39 HURON
" 40 SANILAC
" 41 ST. CLAIR
" 42 LAPEER
" 43 GENESEE
" 44 SHIAWASSEE
" 45 CLINTON
" 46 IONIA
" 47 KENT
" 48 OTTAWA
" 49 ALLEGAN
" 50 BARRY
" 51 EATON
" 52 INGHAM
" 53 LIVINGSTON
" 54 OAKLAND
" 55 MACOMB
" 56 WAYNE
" 57 WASHTENAW
" 58 JACKSON
" 59 CALHOUN
" 60 KALAMAZOO
" 61 VAN BUREN
" 62 BERRIEN
" 63 CASS
" 64 ST. JOSEPH
" 65 BRANCH
" 66 HILLSDALE
" 67 LENAWEE
" 68 MONROE
MICHIGAN
MANITOU IS.
Manistique
St. Ignace
STRAITS OF MACKINAC
LITTLE TRAVERSE BAY
GRAND TRAVERSE BAY
Cheboygan
Harbor Springs
Charlevoix
Rogers
Alpena
Atlanta
Gaylord
Bellaire
Leland
Traverse City
Kalkaska
Frankfort
Grayling
Mio
Harrisville
Roscommon
Lake City
Cadillac
Manistee
Tawas
West Branch
Standish
Harrison
Gladwin
Baldwin
Hersey
Ludington
Grindstone City
Huron
Port Hope
Sand Beach
Bad Axe
SAGINAW BAY



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shall sandstone around to Holland—near which there are outcrops. To the southeast around Allegan, South Haven, and Bangor, the rock surface is considerably lower. How far the softer Michigan series make a trough separating the Marshall ridge from the limestone ridge is not yet clear from the well records. Rapid variations in the altitude of the rock surface around Grand Rapids make it evident that the limestone there is much eroded. Up Grand River, at Ionia, there are other outcrops of a sandstone which is probably high up in the coal series. The rock ridge can be followed, being occasionally struck by wells, to the southeast corner of Newaygo County. From this point north the rock surface evidently falls off, for it is so deep that no ordinary wells for water encounter it, and it is only from deep explorations for salt, oil, or gas that it has been found to fall below sea level at Manistee (30 to 40 feet below tide). It is near these low points in the rock surface that the large limestone masses are found in the drift in Oceana County, and it is not unnatural to suppose that this is in a region of strong relief, whose scenery was something like that of the driftless area of Wisconsin, full of pinnacles capped with limestone. It is here, therefore, that we have carried the stream valley described on page 83, which seems to drain the most of the coal basin surrounded by the Marshall rampart.

The great depth of drift at Traverse City, with the rock bottom not yet reached, compared with Provemont, where the limestone has been struck, shows that on the northwest side again the Coldwater and St. Clair shales make a valley, though outcrops are not far away, and other facts go to support the suggestion that the limestone escarpment on this side was in bold relief and probably severely cut up. In all probability Grand Traverse Bay marks some prominent cross valley. Beyond Cheboygan Lake the limestone ridge becomes more continuous. Throughout the north half of the State the well records of depth to rock are so few that the reconstruction of the rock topography is largely guesswork, and it is necessary to fall back on the analogies of the relations of moraines to rock ridge in the lower part of the State.

PROSPECTS OF ROCK WELLS.

NORTHERN LIMESTONE DISTRICT.

From what has been said in the previous part of this paper in connection with the well reports, it appears that there is a district, from Alpena and Long Rapids to Charlevoix and north of these places, through which it will frequently be necessary, in order to get a permanent supply of water, to drill down into the limestone (Traverse or Dundee), which is often close to the surface. At moderate depths, down to about 500 feet, the water, though hard and slightly charged with hydrogen sulphide (H_2S) will be suitable for drinking. At greater depths, however, within 1,500 feet, rock salt and brines will be encountered.

NORTHERN SHALE DISTRICT.

Toward the south there is a broad district heavily covered with drift, with the rock surface probably a valley in which it will very rarely be necessary to go to rock for drinking waters, and in fact the prospect for them is not very good. The underlying rocks belong to the Carboniferous and Devonian shale series. Only here and there will a deep well, drilled for gas, brine, mineral water, etc., penetrate to the rock and find mineral water beneath the shales.

Toward the south side of this district are the sandstones of the Lower Marshall; but little is yet known of their extent.

COAL BASIN.

The coal basin occupies the center of the State, including in it the Michigan and Upper Marshall series. The basin extends from Tawas Bay probably well up toward Otsego Lake, thence to Ludington and Hart, thence down to Hillsdale County (as shown on the map, Pl. VI). Throughout this district the structure of the rocks is favorable for artesian wells, and inside the belt of moraine that surrounds it there is a very fair chance of getting a flow of water, as at Birch Run, Midland, Bay Port, Sebewaing, and elsewhere. Near the margin of this basin the Upper Marshall sandstone furnishes an abundant supply of the purest water. Toward the center of the basin the overlying Michigan series, with their highly mineralized waters, must be cased off if drinking water is desired. Still nearer the center of the basin almost all the water is slightly saline, but is still quite potable. The limits of the saline waters are roughly shown in fig. 14 (e. g., deeper wells of Saginaw, Ithaca, etc.). The deepest waters now become strong brines, the Upper Marshall becoming remarkably charged with bromine, as at Alma, Midland, and Big Rapids.

SOUTHERN SHALE DISTRICT.

This district, being the southern counterpart of the northern shale district, is the only part of the State where there is any serious difficulty in getting a satisfactory supply of water. It is divided into two parts by the projection of the Marshall sandstone nearly to the Michigan-Ohio-Indiana State boundary. To the southwest there are usually, but not always, ponds and lakes enough for city supplies, and the heavy deposits of overwash valley drift give numerous chances for wells in surface deposits. To the southeast, however, there are practically no lakes below the 800-foot contour. The surface deposits are largely lake clays and clay till, and the underlying rocks shales with subordinate sandstone streaks. These sandstones are likely to be salty or unpleasantly charged with gases. In this region, if a permanent supply can be obtained from cisterns or from the surface gravel ridges, that is probably often the best obtainable, provided due precautions are taken against surface contamination. The Berea sand-

stone seems to be usually salty. It might be worth while to see ho far the sulphureted waters of the Dundee could be cased out and

FIG. 14.—Map showing areas of shallow saline waters in Michigan.

good supply obtained from the Sylvania sandstone. There is no diff culty in this region in getting mineral waters, especially sulphureted

SOUTHEASTERN LIMESTONE DISTRICT.

There only remains to be considered the limestone district of Monroe and southeastern Wayne counties. Here wells just down to or a little way in the rock encounter plenty of water, generally flowing chalybeate, hard, and highly charged with hydrogen sulphide (H_2S). There are plentiful flows of fresh water all the way down, until at 800 feet or less the gypsum and salt layers begin. Naturally the wells draining from the Sylvania sandstone seem to have the best supply, and it might be worth while to go down to it a little farther under cover.

ACKNOWLEDGMENTS.

General acknowledgment is due to a large number of persons who have rendered assistance, mainly by replies to schedules. Thanks are particularly due to L. L. Hubbard, State geologist of Michigan, for free use of data accumulated by the survey and for assistance in many other ways; also to my colleagues on the survey; to Prof. C. A. Davis for information, especially as to Tuscola County, and for hints too numerous to mention; to Prof. W. H. Sherzer and Mr. Cramer for information, especially concerning the southeastern part of the State; and to Dr. C. H. Gordon for information relating to Sanilac County and for hints as to Pleistocene deposits. In this last matter Mr. F. B. Taylor and Mr. Frank Leverett have assisted not only by their publications but by their kindly criticism. Especially in Pl. II data for the southwest part of the State are derived almost wholly from unpublished notes which Mr. Leverett kindly furnished, for the form of which, however, I am entirely responsible. The map in Pl. VII gives the location of those places from which reports have been received, and also indicates the location of public waterworks so far as can be ascertained from these reports, from the Manual of American Waterworks (1897), and from the Michigan Gazetteer. It also indicates, by a special sign, those localities near which flowing wells are reported. It may thus serve to indicate how thoroughly the ground has been covered and in what parts of the State information is still scanty. Above Saginaw Bay the population is sparse.

The paper is least satisfactory in regard to the water powers of the region considered. Those who know the facts consider them too valuable to publish. In this connection the paper by Mr. Robert E. Horton is a welcome addition. The water powers northwest of Saginaw Bay seem especially worth exploiting.

Finally, to the State weather service, C. F. Schneider, director, I am indebted for meteorological data.

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1895.

Sixteenth Annual Report of the United States Geological Survey, 1894–95, Part II, Papers of an economic character, 1895; octavo, 598 pp.

Contains a paper on the public lands and their water supply, by F. H. Newell, illustrated by a large map showing the relative extent and location of the vacant public lands; also a report on the water resources of a portion of the Great Plains, by Robert Hay.

A geological reconnoissance of northwestern Wyoming, by George H. Eldridge, 1894; octavo, 72 pp. Bulletin No. 119 of the United States Geological Survey; price, 10 cents.

Contains a description of the geologic structure of portions of the Bighorn Range and Bighorn Basin, especially with reference to the coal fields, and remarks upon the water supply and agricultural possibilities.

Report of progress of the division of hydrography for the calendar years 1893 and 1894, by F. H. Newell, 1895; octavo, 176 pp. Bulletin No. 131 of the United States Geological Survey; price, 15 cents.

Contains results of stream measurements at various points, mainly within the arid region, and records of wells in a number of counties in western Nebraska, western Kansas, and eastern Colorado.

1896.

Seventeenth Annual Report of the United States Geological Survey, 1895–96, Part II, Economic geology and hydrography, 1896; octavo, 864 pp.

Contains papers on "The underground water of the Arkansas Valley in eastern Colorado," by G. K. Gilbert; "The water resources of Illinois," by Frank Leverett; and "Preliminary report on the artesian areas of a portion of the Dakotas," by N. H. Darton.

Artesian-well prospects in the Atlantic Coastal Plain region, by N. H. Darton, 1896; octavo, 230 pp., 19 plates. Bulletin No. 138 of the United States Geological Survey; price, 20 cents.

Gives a description of the geologic conditions of the coastal region from Long Island, N. Y., to Georgia, and contains data relating to many of the deep wells.

Report of progress of the division of hydrography for the calendar year 1895, by F. H. Newell, hydrographer in charge, 1896; octavo, 356 pp. Bulletin No. 140 of the United States Geological Survey; price, 25 cents.

Contains a description of the instruments and methods employed in measuring streams and the results of hydrographic investigations in various parts of the United States.

1897.

Eighteenth Annual Report of the United States Geological Survey, 1896–97, Part IV, Hydrography, 1897; octavo, 756 pp.

Contains a "Report of progress of stream measurements for the year 1896," by Arthur P. Davis, "The water resources of Indiana and Ohio," by Frank Leverett; "New developments in well boring and irrigation in South Dakota," by N. H. Darton; and "Reservoirs for irrigation," by J. D. Schuyler.

1898.

Nineteenth Annual Report of the United States Geological Survey, 1897–98, Part IV, Hydrography, 1899; octavo, 814 pp.

Contains a "Report of progress of stream measurements for the calendar year 1897," by F. H. Newell and others, "The rock waters of Ohio," by Edward Orton; and "Preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian," by N. H. Darton.

WATER-SUPPLY AND IRRIGATION PAPERS, 1896–1899.

This series of papers is designed to present in pamphlet form the results of stream measurements and of special investigations. A list of these, with other information, is given on the outside (or fourth) page of this cover.

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WATER-SUPPLY AND IRRIGATION PAPERS.

1. Pumping water for irrigation, by Herbert M. Wilson, 1896.
2. Irrigation near Phœnix, Arizona, by Arthur P. Davis, 1897.
3. Sewage irrigation, by George W. Rafter, 1897.
4. A reconnoissance in southeastern Washington, by Israel C. Russell, 1897.
5. Irrigation practice on the Great Plains, by E. B. Cowgill, 1897.
6. Underground waters of southwestern Kansas, by Erasmus Haworth, 1897.
7. Seepage waters of northern Utah, by Samuel Fortier, 1897.
8. Windmills for irrigation, by E. C. Murphy, 1897.
9. Irrigation near Greeley, Colorado, by David Boyd, 1897.
10. Irrigation in Mesilla Valley, New Mexico, by F. C. Barker, 1898.
11. River heights for 1896, by Arthur P. Davis, 1897.
12. Water resources of southeastern Nebraska, by Nelson Horatio Darton, 1898.
13. Irrigation systems in Texas, by William Ferguson Hutson, 1898.
14. New tests of certain pumps and water lifts used in irrigation, by O. P. Hood, 1898.
15. Operations at river stations, 1897, Part I, 1898.
16. Operations at river stations, 1897, Part II, 1898.
17. Irrigation near Bakersfield, California, by C. E. Grunsky, 1898.
18. Irrigation near Fresno, California, by C. E. Grunsky, 1898.
19. Irrigation near Merced, California, by C. E. Grunsky, 1899.
20. Experiments with windmills, by Thomas O. Perry, 1899.
21. Wells of northern Indiana, by Frank Leverett, 1899.
22. Sewage irrigation, Part II, by George W. Rafter, 1899.
23. Water-right problems in the Bighorn Mountains, by Elwood Mead, 1899.
24. Water resources of the State of New York, Part I, by George W. Rafter, 1899.
25. Water resources of the State of New York, Part II, by George W. Rafter, 1899.
26. Wells of Southern Indiana, by Frank Leverett, 1899.
27. Operations at river stations, 1898, Part I, 1899.
28. Operations at river stations, 1898, Part II, 1899.
29. Wells and windmills in Nebraska, by Erwin Hinckley Barbour, 1899.
30. Water resources of the Lower Peninsula of Michigan, by Alfred C. Lane, 1899.

In addition to the above there are, in various stages of preparation, other papers, relating to the measurement of streams, the storage of water, the amount available from underground sources, the efficiency of windmills, the cost of pumping, and other details relating to the methods of utilizing the water resources of the country. Provision has been made for printing these by the following clause in the sundry civil act making appropriations for the year 1896–97:

Provided, That hereafter the reports of the Geological Survey in relation to the gauging of streams and to the methods of utilizing the water resources may be printed in octavo form, not to exceed 100 pages in length and 5,000 copies in number; 1,000 copies of which shall be for the official use of the Geological Survey, 1,500 copies shall be delivered to the Senate, and 2,500 copies shall be delivered to the House of Representatives, for distribution. (Approved, June 11, 1896: Stat. L., vol. 29, p. 453.)

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DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 31

LOWER MICHIGAN MINERAL WATERS.—LANE

WASHINGTON
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1899

IRRIGATION REPORTS.

The following list contains titles and brief descriptions of the principal reports relating to water supply and irrigation, prepared by the United States Geological Survey since 1890:

1890.

First Annual Report of the United States Irrigation Survey, 1890; octavo, 123 pp.

Printed as Part II, Irrigation, of the Tenth Annual Report of the United States Geological Survey, 1888-89. Contains a statement of the origin of the Irrigation Survey, a preliminary report on the organization and prosecution of the survey of the arid lands for purposes of irrigation, and report of work done during 1890.

1891.

Second Annual Report of the United States Irrigation Survey, 1891; octavo, 395 pp.

Published as Part II, Irrigation, of the Eleventh Annual Report of the United States Geological Survey, 1889-90. Contains a description of the hydrography of the arid region and of the engineering operations carried on by the Irrigation Survey during 1890; also the statement of the Director of the Survey to the House Committee on Irrigation, and other papers, including a bibliography of irrigation literature. Illustrated by 29 plates and 4 figures.

Third Annual Report of the United States Irrigation Survey, 1891; octavo, 376 pp.

Printed as Part II of the Twelfth Annual Report of the United States Geological Survey, 1890-91. Contains "Report upon the location and survey of reservoir sites during the fiscal year ended June 30, 1891," by A. H. Thompson; "Hydrography of the arid regions," by F. H. Newell; "Irrigation in India," by Herbert M. Wilson. Illustrated by 93 plates and 190 figures.

Bulletins of the Eleventh Census of the United States upon irrigation, prepared by F. H. Newell; quarto.

No. 35, Irrigation in Arizona; No. 60, Irrigation in New Mexico; No. 85, Irrigation in Utah; No. 107, Irrigation in Wyoming; No. 153, Irrigation in Montana; No. 157, Irrigation in Idaho; No. 163, Irrigation in Nevada; No 178, Irrigation in Oregon; No. 193, Artesian wells for irrigation; No. 198, Irrigation in Washington.

1892.

Irrigation of western United States, by F. H. Newell; extra census bulletin No. 23, September 9, 1892; quarto, 22 pp.

Contains tabulation showing the total number, average size, etc., of irrigated holdings, the total area and average size of irrigated farms in the subhumid regions, the percentage of number of farms irrigated, character of crops, value of irrigated lands, the average cost of irrigation, the investment and profits, together with a résumé of the water supply and a description of irrigation by artesian wells. Illustrated by colored maps, showing the location and relative extent of the irrigated areas.

1893.

Thirteenth Annual Report of the United States Geological Survey, 1891-92, Part III, Irrigation, 1893; octavo, 486 pp.

Consists of three papers: "Water supply for irrigation," by F. H. Newell; "American irrigation engineering" and "Engineering results of the Irrigation Survey," by Herbert M. Wilson; "Construction of topographic maps and selection and survey of reservoir sites," by A. H. Thompson. Illustrated by 77 plates and 129 figures.

A geological reconnoissance in central Washington, by Israel Cook Russell, 1893; octavo, 108 pp., 15 plates. Bulletin No. 108 of the United States Geological Survey; price, 15 cents.

Contains a description of the examination of the geologic structure in and adjacent to the drainage basin of Yakima River and the great plains of the Columbia to the east of this area, with special reference to the occurrence of artesian waters.

1894.

Report on agriculture by irrigation in the western part of the United States at the Eleventh Census, 1890, by F. H. Newell, 1894; quarto, 283 pp.

Consists of a general description of the condition of irrigation in the United States, the area irrigated, cost of works their value and profits; also describes the water supply, the value of water, of artesian wells, reservoirs, and other details; then takes up each State and Territory in order, giving a general description of the condition of agriculture by irrigation, and discusses the physical conditions and local peculiarities in each county.

Fourteenth Annual Report of the United States Geological Survey, 1892-93, in two parts: Part II, Accompanying papers, 1894; octavo, 507 pp.

Contains papers on "Potable waters of the eastern United States," by W J McGee; "Natural mineral waters of the United States," by A. C. Peale; "Results of stream measurements," by F. H. Newell. Illustrated by maps and diagrams.

(Continued on third page of cover.)

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IRRIGATION PAPERS

OF THE

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1899

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CHARLES D. WALCOTT, DIRECTOR

LOWER MICHIGAN MINERAL WATERS

A STUDY INTO THE CONNECTION BETWEEN THEIR CHEMICAL COMPOSITION AND MODE OF OCCURRENCE

BY

ALFRED CHURCH LANE

WASHINGTON

GOVERNMENT PRINTING OFFICE

1899

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LETTER OF TRANSMITTAL.

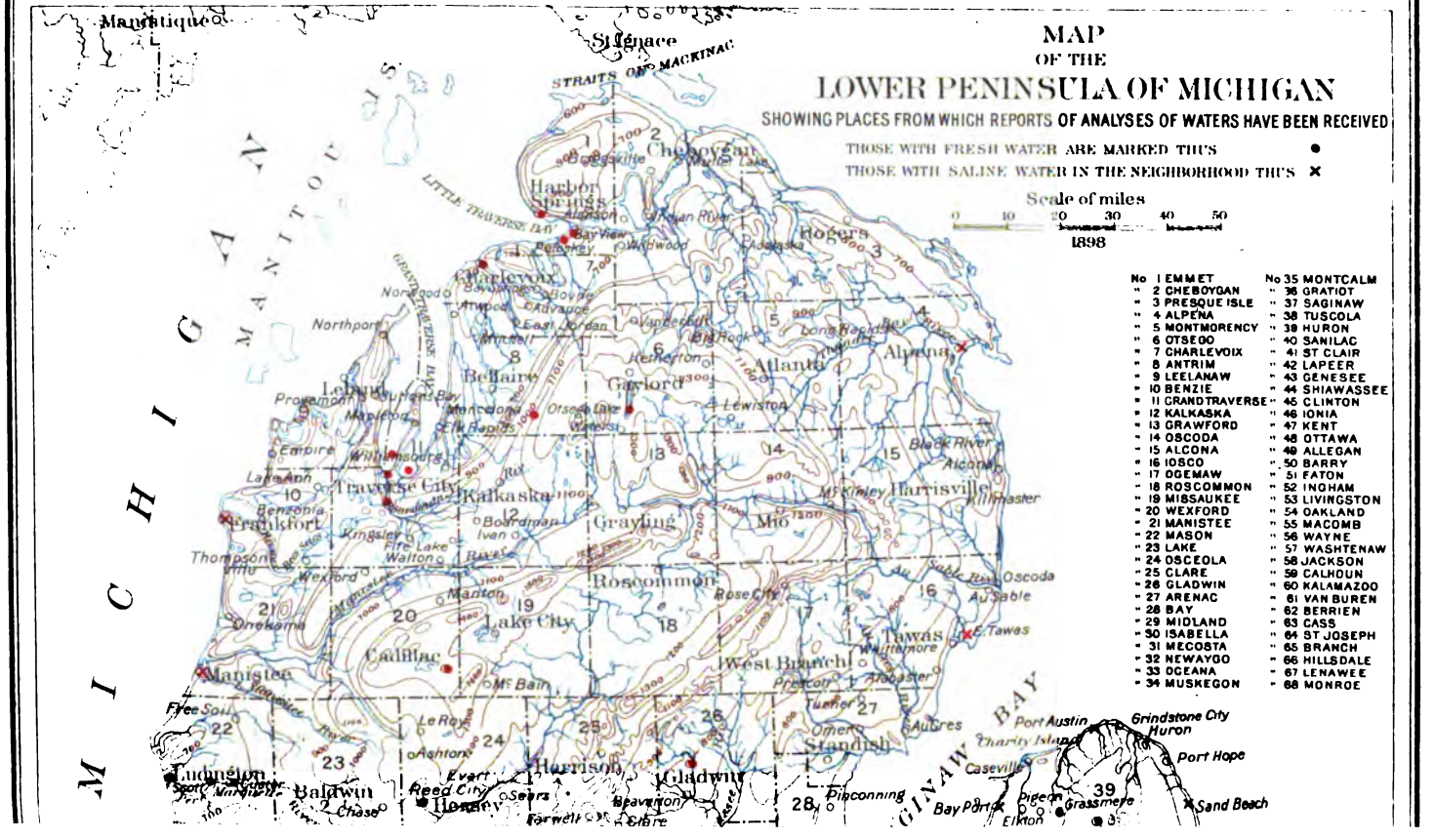
DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, May 15, 1899.

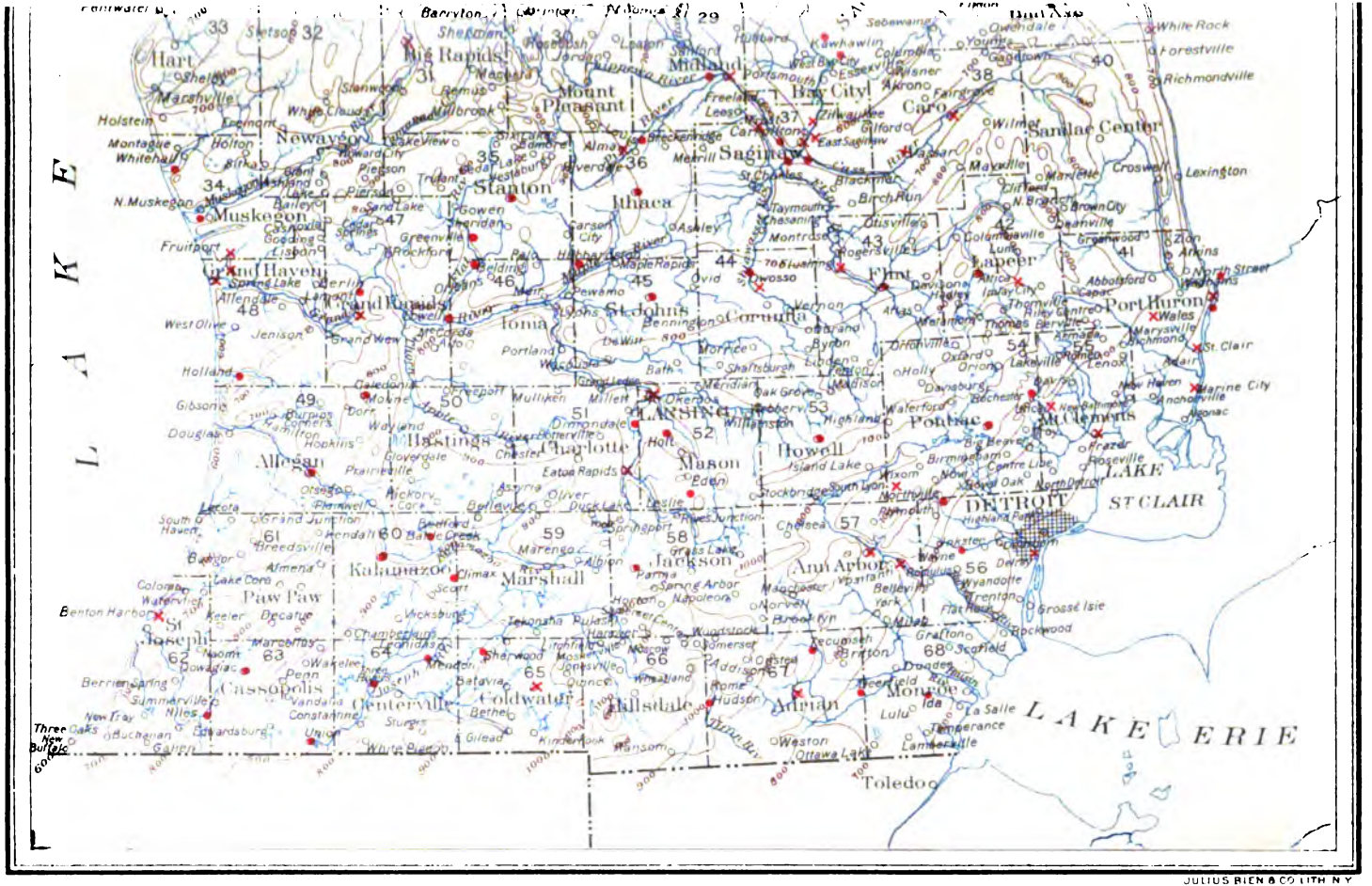
SIR: I have the honor to transmit herewith a manuscript on the mineral waters of the Lower Peninsula of Michigan, by Dr. Alfred Church Lane, now State geologist of Michigan, and to recommend that it be printed as one of the series of Water-Supply and Irrigation Papers. This is a continuation of Water-Supply Paper No. 30, entitled Water Resources of the Lower Peninsula of Michigan. The original plan was to have this and related information published as one report or monograph. It has been considered desirable, however, to issue the separate chapters or groups of chapters of the report as originally designed in pamphlet form, in order to insure an earlier publication and to facilitate the completion of portions for which an unexpected wealth of detail has been found. In this part of the report the water analyses have been brought together and discussed, particular attention having been paid to the relation which exists between the chemical composition and the geological horizons or mode of occurrence of the waters carrying mineral matter in solution.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.


MAP
OF THE
LOWER PENINSULA OF MICHIGAN
SHOWING PLACES FROM WHICH REPORTS OF ANALYSES OF WATERS HAVE BEEN RECEIVED
THOSE WITH FRESH WATER ARE MARKED THUS ●
THOSE WITH SALINE WATER IN THE NEIGHBORHOOD THUS ×
Scale of miles
0 10 20 30 40 50
1898
No 1 EMMET
" 2 CHEBOYGAN
" 3 PRESQUE ISLE
" 4 ALPENA
" 5 MONTMORENCY
" 6 OTSEGO
" 7 CHARLEVOIX
" 8 ANTRIM
" 9 LEELANAW
" 10 BENZIE
" 11 GRANDTRAVERSE
" 12 KALKASKA
" 13 GRAWFORD
" 14 OSCODA
" 15 ALCONA
" 16 IOSCO
" 17 OGEMAW
" 18 ROSCOMMON
" 19 MISSAUKEE
" 20 WEXFORD
" 21 MANISTEE
" 22 MASON
" 23 LAKE
" 24 OSCEOLA
" 25 CLARE
" 26 GLADWIN
" 27 ARENAC
" 28 BAY
" 29 MIDLAND
" 30 ISABELLA
" 31 MECOSTA
" 32 NEWAYGO
" 33 OCEANA
" 34 MUSKEGON
No 35 MONTCALM
" 36 GRATIOT
" 37 SAGINAW
" 38 TUSCOLA
" 39 HURON
" 40 SANILAC
" 41 ST CLAIR
" 42 LAPEER
" 43 GENESEE
" 44 SHIAWASSEE
" 45 CLINTON
" 46 IONIA
" 47 KENT
" 48 OTTAWA
" 49 ALLEGAN
" 50 BARRY
" 51 EATON
" 52 INGHAM
" 53 LIVINGSTON
" 54 OAKLAND
" 55 MACOMB
" 56 WAYNE
" 57 WASHTENAW
" 58 JACKSON
" 59 CALHOUN
" 60 KALAMAZOO
" 61 VAN BUREN
" 62 BERRIEN
" 63 CASS
" 64 ST JOSEPH
" 65 BRANCH
" 66 HILLSDALE
" 67 LENAWEE
" 68 MONROE
MICHIGAN
MANITOU IS.
Manistique
St Ignace
STRAITS OF MACKINAC
Cheboygan
Harbor Springs
Rogers
Charlevoix
Northport
Alpena
Atlanta
Gaylord
Bellaire
Lelanau
Traverse City
Kalkaska
Frankfort
Grayling
Mio
Harrisville
Roscommon
Lake City
Cadillac
Manistee
Tawas
West Branch
Standish
Ludington
Baldwin
Hesseo
Harrison
Gladwin
Pinconning
Bay Port
Elkton
Pigeon
Grassmere
Sand Beach
Port Austin
Grindstone City
Huron
Port Hope
Caseville
Charity Island
GINAW BAY


LAKE ERIE
LAKE ST CLAIR
DETROIT
Toledo
Hart
Big Rapids
Midland
Bay City
Saginaw
Caro
Sandlac Center
Newaygo
Mount Pleasant
Stanton
Ithaca
Muskegon
Grand Haven
Grand Rapids
St Johns
Corunna
Flint
Lapeer
Port Huron
Pontiac
Mt Clemens
Howell
LANSING
Hastings
Charlotte
Mason
Allegan
Kalamazoo
Marshall
Jackson
Ann Arbor
Paw Paw
St Joseph
Benton Harbor
Cassopolis
Centerville
Coldwater
Hillsdale
Adrian
Monroe
Tecumseh
Brighton
Milford
Howell
Fowlerville
Williamston
Okemos
Holt
Eaton Rapids
Leslie
Dansville
Mason
Eden
Stockbridge
Chelsea
Dexter
Saline
Ypsilanti
Belleville
Wayne
Plymouth
Northville
Livonia
Farmington
Birmingham
Royal Oak
Troy
Roseville
Grosse Isle
Trenton
Flat Rock
Rockwood
Grafton
Scofield
Dundee
Deerfield
Ida
Lulu
La Salle
Temperance
Lambertville
Ottawa Lake
Weston
Ransom
Hudson
Addison
Jonesville
Litchfield
Somerset
Napoleon
Spring Arbor
Parma
Albion
Marengo
Battle Creek
Bellevue
Climax
Vicksburg
Schoolcraft
Three Rivers
Sturgis
Constantine
Centreville
Union
White Pigeon
Niles
New Buffalo
Buchanan
Edwardsburg
Galien
Berrien Springs
Summerville
Dowagiac
Cassopolis
Vandalia
Penn
Wakeeley
Jones
Sherwood
Athens
Batavia
Quincy
Bethel
Gilead
Kinderhook
Union
Sturgis
Constantine
Centreville
White Pigeon
Three Rivers
Schoolcraft
Vicksburg
Climax
Battle Creek
Bellevue
Marengo
Albion
Parma
Spring Arbor
Napoleon
Norvell
Brooklyn
Manchester
Saline
Dexter
Chelsea
Grass Lake
Jackson
Leslie
Eaton Rapids
Holt
Mason
Eden
Stockbridge
Howell
Fowlerville
Williamston
Okemos
Meridian
Haslett

LOWER MICHIGAN MINERAL WATERS: A STUDY INTO THE CONNECTION BETWEEN THEIR CHEMICAL COMPOSITION AND MODE OF OCCURRENCE.

By ALFRED CHURCH LANE.

INTRODUCTION.

This paper is the outcome of certain work in the Lower Peninsula of Michigan which I undertook for the State survey in 1895, and was originally planned as Chapter V of a paper of which the first four chapters have appeared as Water-Supply Paper No. 30.[1] The remainder of the material will be published in a later number of this series. To these two pamphlets frequent reference must be made, and they should be considered supplementary to the present paper.

In the region of the Saginaw Valley the country is exceedingly flat, and rock exposures are rare, so that for light on the detailed geology of the subsurface rocks of the region we are compelled to rely on well records—largely the untrustworthy data derived from pulverized drillings and the inferences that can be drawn therefrom concerning the rock topography—and on the characters of the waters. It was found, however, that the waters gave important objective clues, and our party carried a testing case of barium chloride, silver nitrate, ammonium oxalate, and tannic acid, a urinometer, and a thermometer, instead of the geologist's hammer. The work I had previously done in connection with the preparation of Volume V of the State reports led me to think that in general it was probably true that the various geological horizons yielded characteristic waters; therefore during the year 1897, with the guidance and support of Mr. F. H. Newell, I attempted, by means of circulars and personal visits, to extend my investigations of the waters of Michigan. I met with such hearty cooperation from the chemists connected with State institutions—Profs. R. C. Kedzie and F. S. Kedzie, of the State Agricultural College, Prof. A. B. Prescott, of the State University, and Prof. V. C. Vaughan—that the analytical material outgrew the limits of a chapter, and I began to gain a somewhat complete idea of the chemico-geological relations of the waters of the State.

[1] Water resources of the Lower Peninsula of Michigan, by Alfred C. Lane: Water-Supply and Irrigation Paper No. 30, 1899.

Besides the gentlemen named, who have contributed many analyses, I owe acknowledgments to many other chemists who have also contributed or verified analyses for me—Messrs. Edgar and Mariner, of Chicago, Prof. S. P. Duffield, C. A. Tonnelé, and Geo. L. Heath—and to resort proprietors, secretaries of water boards, and others, too numerous to mention here, who have answered circulars of inquiry.

It is not the purpose of this report to treat the general subject of water resources or water supply, which has been discussed in a general and somewhat cursory way in Water-Supply Paper No. 30, and will be taken up for the different localities in a later paper, but to show that the chemical composition of water depends on the geological occurrence, so that from a given geological stratum at a given depth a certain kind of water may be expected; and that, vice versa, the geological horizon can be inferred to a certain extent from the character of the water.

To physicians and others who are interested in the famous mineral resources of the State in a practical way, I would recommend, in addition, the pamphlet issued by the State board of health, entitled Michigan, a Summer and Health Resort, compiled by Roberts P. Hudson, Lansing, 1898. That paper is fully illustrated and contains much practical information about railroad fares, etc. At the same time the present paper, since it contains the most complete collection of analyses to date, may be of service in pointing out waters of similar character, among which a choice can be based on climate or other considerations. It will also assist in a study of the drinking-water supply in connection with disease, by giving an idea of the normal percentages of chlorine, organic matter, etc., deviation from which must be regarded with suspicion.

ECONOMIC VALUE OF MINERAL WATERS.

MEDICINAL PROPERTIES.

The various inorganic impurities which unfit water for domestic and ordinary uses may be of value from a medicinal point of view. Thus the waters of many wells in the western part of Huron and the northwestern part of Tuscola County are laxative to men and cattle not accustomed to them, though regular users may not experience such effects. Sodium sulphate is a common laxative constituent in Saginaw waters.

The mineral table waters are derived from various sources, largely sandstones or the surface gravels. The Moorman well at Ypsilanti is concentrated to throw down the lime salts and then diluted and charged with CO_2. Other table waters also seem to be diluted salines. The main horizon for bathing purposes developed at Ypsilanti, Mount Clemens, Alma, Benton Harbor, etc., is that of limestones immediately underlying the Devonian black shales. In the Berea formation just above, and again upon entering the Traverse or Hamilton formation, a very salty mineral water, with gas or oil, is struck, and in the upper Hel-

derberg (Dundee limestone) a water strongly mineralized with hydrogen sulphide. Unfortunately care is rarely taken to separate the constituents of the different flows. There are distinct indications that the first "bitter" water struck in the lower Helderberg contains in concentration rarer constituents, the earthy chlorides and H_2S, and that what is added below is mainly salt.

For the Mount Clemens wells it is customary to continue down until a satisfactory buoyancy, measured with the salinometer, is obtained, so that bathers can feel the strength of the water.

The waters from the upper Dundee (Corniferous, or upper Helderberg) or Mackinac limestone are usually strongly sulphated, and even where fresher at their margin, as at Petoskey, they are still characteristically sulphureted.

The Big Rapids well is apparently from a different horizon, the Marshall sandstone, as encountered in Midland, St. Johns, and Alma (upper water).

From these waters the salts can be extracted for medicinal purposes, as at Ypsilanti, Alma, and Big Rapids, or for their general value.

SALT AND SODA COMPOUNDS.

The production of common salt is a well-known industry of Michigan, fully treated in recent reports of the United States Geological Survey, so that only brief mention is necessary here. The State has produced altogether about 75,000,000 barrels (of 284 pounds), and in 1898 produced about 4,171,916 barrels. The production has been dying out in the Saginaw Valley, as the supply of lumber waste for fuel disappeared, and in Huron County, once lined with salt blocks, only one is left, the profit of which comes from local trade; but with the development of local coal fields the industry will be revived. On the other hand, the industry is increasing around Manistee, and also along the Detroit River, from Detroit to Trenton, where the production of salt is closely allied with that of soda ash, bleaching powder, etc. This latter district is exceptionally favored in possessing strong pure brines, strong and pure limestone, and excellent transportation facilities. Near Alpena the same favorable conditions exist, but that region is not yet developed. It has been proposed to mine the salt near Detroit, instead of pumping it, as has hitherto been the universal rule, and thus convert the deposit from a water resource to a mineral resource. While there is no law against pumping the salt out from under a man's property without compensation, it is illegal to mine it, so that pumping has the advantage of evading royalties. Newspapers report that the difficulty of sinking a shaft in face of heavy flows of water is the chief obstacle.

BROMINE.

Among the most important minor ingredients of the Michigan brines is bromine. The analyses from Midland (Nos. 281–284), Alma (Nos. 327–329), and Big Rapids (No. 278) are noteworthy for this constituent;

the Sand Beach (Nos. 324–326) and later analyses should also be compared.

The most active manufacture of bromine is at Midland, where the brine is treated for this product alone by the Dow process. The bromine seems to be concentrated in the deeper central parts of the basin, and to be more abundant in the Marshall than in any other formation.

The analyses also show other ingredients of value, but their exploitation has not gone far yet. The most promising field for further study and exploitation appears to be that of potash. Patents have been issued for the use of mother liquors of brines as an electric excitant, and the use of calcium chloride in preserving fruit, in drying, in refrigerating, and in the manufacture of artificial stone, is well known. The utilization of mother liquors has not gone far as yet.

DISCUSSION OF ANALYTICAL STATEMENTS.

DIFFICULTIES.

The analyses given in this paper are stated in various ways, according to the practice of the chemist who prepared them. I have tried to convert them all into the uniform system of grams per kilogram or parts per thousand. But it is at present practically impossible to reduce them to absolute uniformity.

In the first place, they are variously stated in grams per liter, grains per gallon, and parts per thousand, per hundred thousand, or per million. In regard to the former statements there are two uncertainties that arise. First, is the gallon imperial or United States? In most cases I have been able to remove this ambiguity. Second, was the specific gravity of the water taken into account, or was it neglected, as is customary in potable waters?[1] In other words, was the gallon or liter weighed or measured? Professor Prescott and T. Tonnelé state the results of their analyses both in parts per million and in grains per United States gallon, allowing for the specific weight of the gallon, although often only one statement is published. Professor Kedzie uses the imperial gallon of 10 pounds (70,000 grains), which is really a weight, not a measure. Professor Duffield also has used the imperial gallon, but of late uses the United States gallon of 231 cubic inches. Both weigh the waters and the specific gravity does not enter into the computation. Professor Vaughan reports in parts per million. The water is usually measured and the specific gravity neglected, as his sanitary analyses are potable waters with specific weight usually unity. Occasionally, as at Mount Pleasant, this introduces a sensible error. Messrs. Edgar and Mariner, of Dearborn Chemical Works, use the United States gallon of 231 cubic inches. In doubtful cases the imperial gallon can often be recognized by the fact that the figures of the analysis will be divisible by 7. In

[1] Missouri Geological Survey, Vol. III., p. 22.

most other cases, but not in all, I have been able to ascertain definitely, by personal inquiry, concerning this matter. The United States gallon is commonly used by the mechanical profession (for instance, by the Railway Master Mechanics' Association), and therefore generally in analyses of boiler waters. It is much to be desired that all analyses should be stated explicitly in grams per kilogram—i. e., in parts per thousand by weight—for even statements in grams per liter are sometimes really in grams per kilogram. If this form of statement is not considered so intelligible as some other expression, a note might be added calling attention to the fact that, neglecting the specific gravity, one gram per kilogram, or one part per thousand, is practically 1 ounce per cubic foot, or 1 pound avoirdupois in 120 gallons. I have restated most of the analyses in parts per thousand by weight, but, as a check, in the case of newly published analyses, have also given the original figures in italics.

But if these difficulties are once surmounted there remains, in the second place, an even more serious obstacle in the fact that the partition of acids among bases is largely a matter of choice. For instance, the bromine is sometimes given as sodic and sometimes as magnesic bromide. This must necessarily be the case so far as real combinations are concerned, and there are no universally adopted conventions. Even the few laws more or less made out, such as that $CaCO_3$ is insoluble in a saturated brine, are not always followed (see analysis No. 312). When the acids and the bases have also been given separately I have given this form also, but such a statement seems less suggestive; perhaps were it more used it would not seem so.

Finally, there is the fact that a mineral water, especially when charged with gas, as most of them are, is exceedingly unstable, and when concentrated extremely corrosive, as is witnessed by the rapid destruction of casings and bathroom fixtures. This also makes analyses uncertain and hard to compare.

Among the constituents most puzzling in this respect are the carbonates and bicarbonates, especially of iron. It is practically impossible to get the same amount of CO_2 from a carbonated water, and it is probable that more than three grains to the gallon of $CaCO_3$ (0.04 per thousand) can not ordinarily exist in a noncarbonated water, the excess of lime shown in so many analyses being in the form of calcium bicarbonate. At the Agricultural College, from the average of the results of tests by a class of from seven to ten students, the hydrant water from a deep artesian well contains 4.75 degrees of temporary and 4.714 degrees of permanent hardness, the total hardness being 9.605. After aeration and heating in the purifier the hardness was reduced to 1.68 degrees temporary and 2.554 degrees permanent, or 4.237 degrees in all. A series of tests of samples of lake and well water collected by D. J. Hale and analyzed for free CO_2, $CaCO_3$, and $MgCO_3$ by A. N. Clark, showed free CO_2 ranging from 0.0 to 66 parts per million, using phenol phthalein

as an indicator. The same thing is even more true of iron. According to Schweitzer,[1] in a chalybeate water with much gypsum one-fourth of the iron is present as carbonate and three-fourths as sulphate. Yet some analyses show more $CaCO_3$ than can be present except dissolved in H_2CO_3.

On the other hand, field observations about mineral wells have convinced me that in many cases the iron has been precipitated before the sample reached the chemist, and therefore escaped analysis. The effect of iron in solution is so marked on tea, and in precipitation as boiler or teakettle scale it is so conspicuous, that the field observer can hardly be mistaken in noticing it. But the question may often arise whether the iron is an original and essential constituent of the water or is derived from the casing of the well.

Other observations, such as exhalations and deposits, as well as the quantity and character of the boiler scale, etc., serve as checks on analyses. When, as Professor Sherzer has pointed out, native sulphur and celestite are crystallized together, as they are so characteristically at Scofield, it can hardly be amiss to assume that a trace of strontia was present in the sulphureted water, even though it is but rarely noted in the analyses. In this connection the amount of Sr shown in the analysis of Lake Superior water is noteworthy. Among the analyses those of waters from the Dundee limestone most frequently mention SrO.

Again, in Michigan, as elsewhere, certain algæ luxuriate and grow with remarkable rapidity in the deeper bicarbonated waters.

REDUCTION FACTORS.

Considering all the uncertainties mentioned as inherent in analyses, and the fact that by various methods of computation the number of grains to the United States gallon varies from 58,418.6092 to 58,372.3, the approximate reduction factors cited below are usually sufficiently accurate. Reduction of analyses from grains per United States gallon have been made by slide rule. For further details see report by Dr. A. C. Peale,[2] and references there given.

Table of equivalents.

1 United States liquid gallon = 231 cubic inches = 8.33888 pounds avoirdupois = 58,372.3 grains = 8 wine pints.

1 imperial gallon = 277.274 cubic inches = 10 pounds avoirdupois = 70,000 grains.

1 liter = 0.264179 United States liquid gallon = 0.22009 Imperial gallon.

1 gram = 15.432 grains.

Approximations.

1 part per thousand by weight = 1 gram per kilogram, or (neglecting specific gravity) = 1 gram per liter = 1 ounce per cubic foot.

To reduce grains per imperial gallon to grams per liter divide by 70.

To reduce grains per United States gallon to grams per liter multiply by 1.2 and divide by 70.

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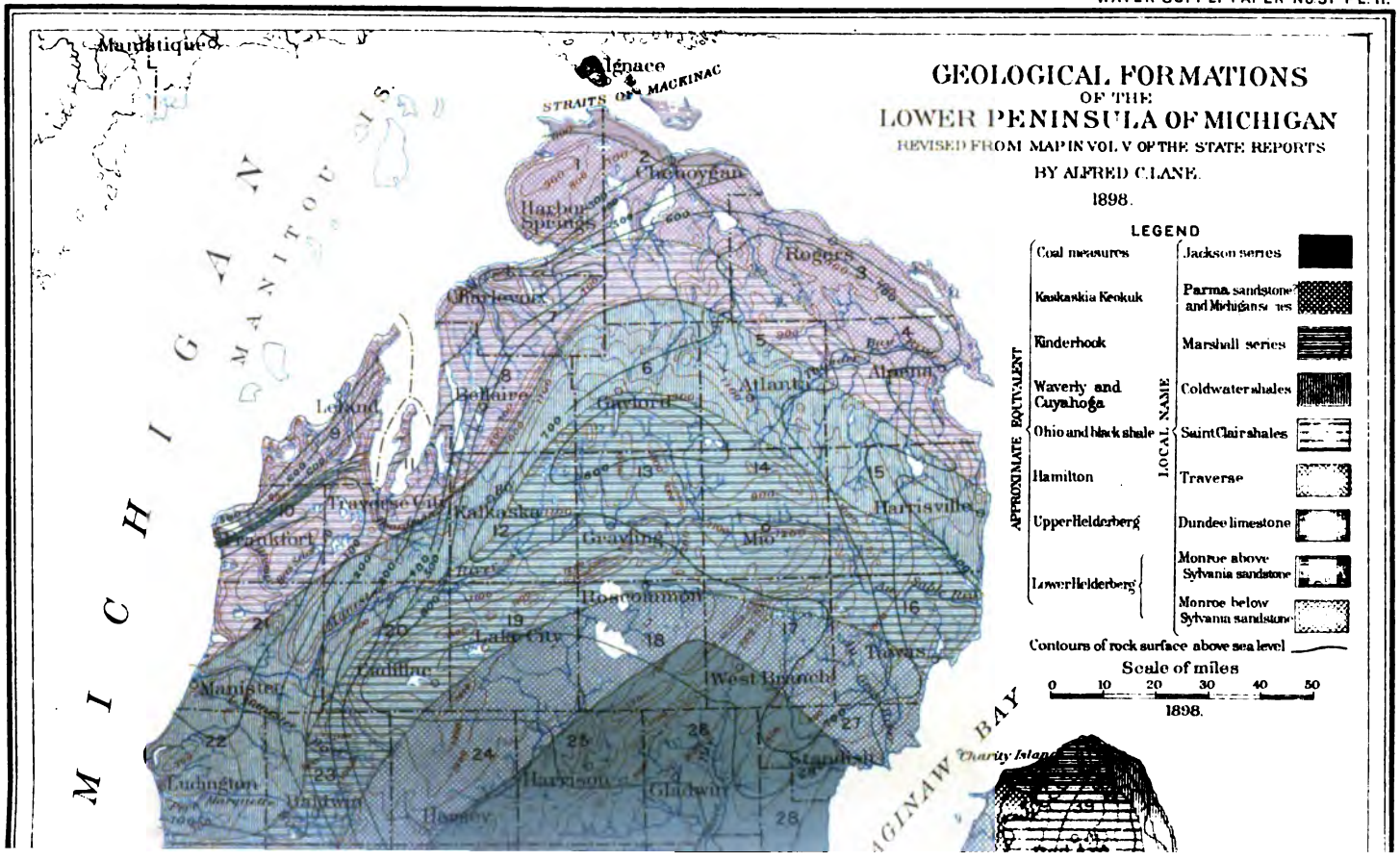
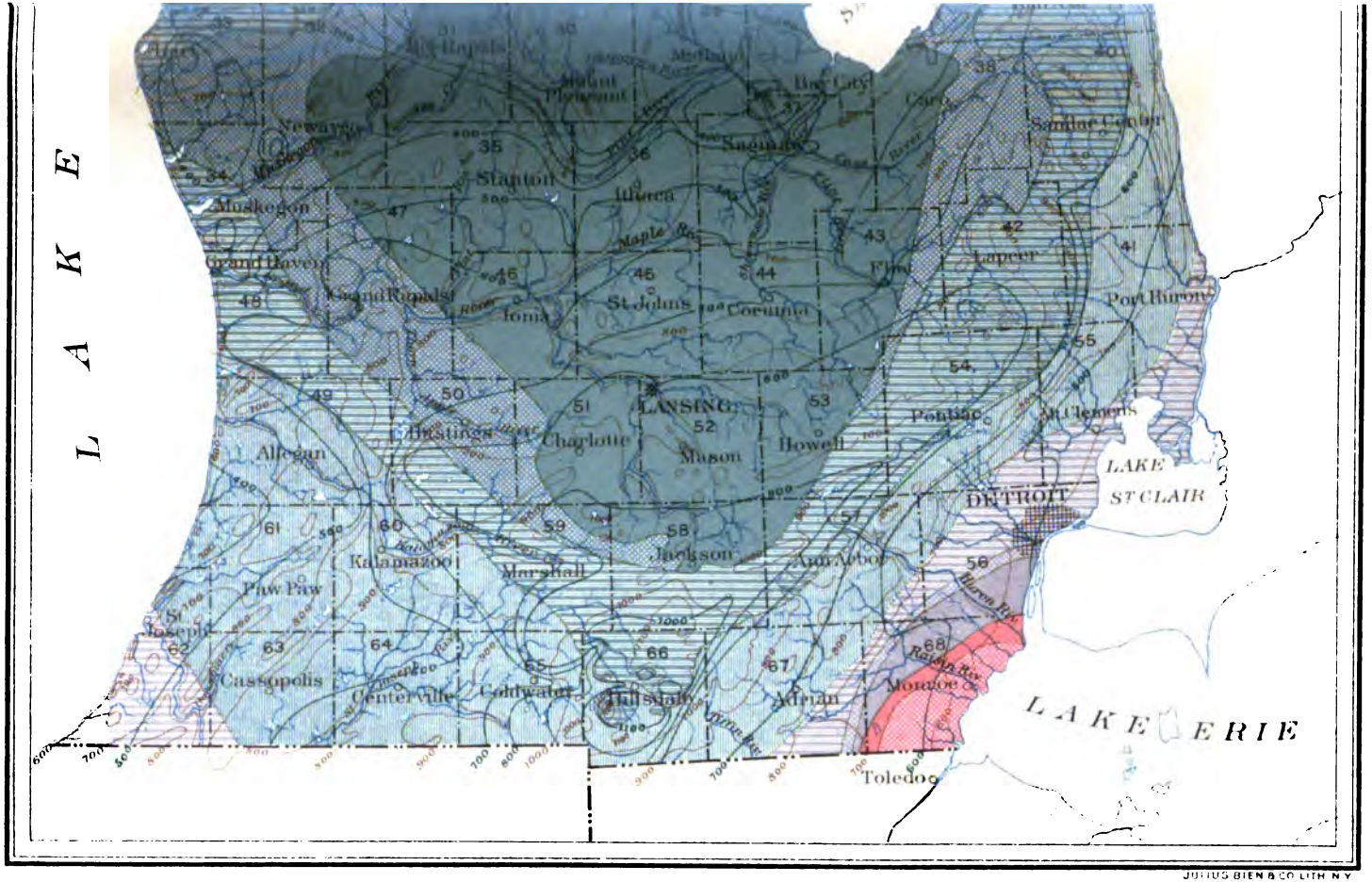
[1] Missouri Geological Survey, Vol. III, p. 19.

[2] Natural mineral waters of the United States, by A. C. Peale: Fourteenth Ann. Rept. U. S. Geol. Survey (1892-93), Part II, 1894, pp. 49-88.


GEOLOGICAL FORMATIONS
OF THE
LOWER PENINSULA OF MICHIGAN
REVISED FROM MAP IN VOL. V OF THE STATE REPORTS
BY ALFRED C. LANE.
1898.
LEGEND
APPROXIMATE EQUIVALENT
Coal measures
Kaskaskia Keokuk
Kinderhook
Waverly and Cuyahoga
Ohio and black shale
Hamilton
Upper Helderberg
Lower Helderberg
LOCAL NAME
Jackson series
Parma sandstone and Michigan series
Marshall series
Coldwater shales
Saint Clair shales
Traverse
Dundee limestone
Monroe above Sylvania sandstone
Monroe below Sylvania sandstone
Contours of rock surface above sea level
Scale of miles
0 10 20 30 40 50
1898.
MICHIGAN
MANITOU IS.
Manistique
Ignace
STRAITS OF MACKINAC
Cheboygan
Harbor Springs
Rogers
Charlevoix
Atlanta
Alpena
Belleire
Gaylord
Leland
Traverse City
Kalkaska
Frankfort
Harrisville
Grayling
Mio
Roscommon
Lake City
Cadillac
Manistee
West Branch
Tawas
Standish
Ludington
Baldwin
Harrison
Gladwin
Hersey
Charity Island
AGINAW BAY


L A K E
Muskegon
Grand Haven
Grand Rapids
Stanton
Ithaca
Alma
Mount Pleasant
Bay City
Saginaw
Saginaw Bay
Flint
Lapeer
Port Huron
St Johns
Corunna
Ionia
LANSING
Hastings
Charlotte
Mason
Howell
Pontiac
Mt Clemens
Allegan
LAKE ST CLAIR
DETROIT
Ann Arbor
Jackson
Kalamazoo
Marshall
Paw Paw
St Joseph
Cassopolis
Centerville
Coldwater
Hillsdale
Adrian
Monroe
LAKE ERIE
Toledo
JULIUS BIEN & CO LITH N Y

To reduce grains per imperial gallon to grains per United States gallon multiply by $\frac{5}{6}$.

Roughly, to reduce degrees salinometer or urinometer, etc.:

Urinometer reading = excess of specific gravity over 1 in thousandths = 2 × salinometer reading = 8 × per cent of salt or the Beaumé reading.

In estimating flows:

1 pail is usually 3 gallons.

1 barrel is usually 31½ gallons = 4 bushels = 128 quarts; sometimes 3 bushels.

1 cubic foot = 1,000 ounces fluid or avoirdupois = 30 quarts, roughly.

1 cubic foot per second = 30 quarts per second = about 150 3-gallon pails a minute = 20,000 4-bushel barrels a day = about 650,000 gallons a day.

In the Saginaw Valley the flow of the brine wells was estimated by noting the number of seconds required to fill a pail when pumping as hard as possible without pounding. Thus, a well might be known as an eight-, a ten-, or a twelve-second well, and when all were pumped a well of eleven seconds would fall off to twenty seconds.

CLASSIFICATION OF ANALYSES.

The geological occurrence and the chemical character of water are clearly interdependent, so that with some probability one may be inferred from the other. It has therefore seemed best to group together, for the purposes of comparison and study, analyses from geologically similar sources rather than to follow the alphabetical order. The analyses are generally arranged also in order of increasing concentration—i. e., of increase in the total amount of solids. To this rule there are, however, some exceptions, for I have grouped together analyses of waters from the same place and from substantially the same source, where the presumption is that the variation in concentration is accidental. The rather large groups of sanitary analyses of unknown geological environment, which I owe to Professor Vaughan and to Profs. R. C. and F. S. Kedzie, being fuller in some points and not so full in others, have been kept together, so that they may be more easily tabulated and compared. I have also grouped in a separate section those analyses the geological relations of which were somewhat uncertain, and which I did not therefore care to make use of in drawing deductions as to the character of the waters of the different strata.

The alphabetical index at the end of the paper will enable one to study the variation of chemical composition in waters from wells of varying depths at the same place. Among the places most instructive in this respect are Saginaw, Bay City, Midland, Alma, Detroit, and Ypsilanti.

The waters may be divided geologically into waters of the Great Lakes system, of rivers and smaller lakes, of wells and springs in the unconsolidated deposits, and of wells from beds above the Marshall (which are stronger in sulphates), in the Marshall, in the Berea grit (saline), and in beds below the Berea (sulphureted). To each group is given a section below.

In all analyses the results are in parts per thousand (grams per kilogram) unless otherwise stated. Where two sets of figures are given, the lower refer to parts per thousand. This is done in the case of analyses not, to my knowledge, elsewhere on record, and for which I have had to compute the lower figures from other forms of statement. As a check the original figures are given above them in italics.

In all the sanitary analyses by Professor Vaughan the color is clear, unless otherwise stated, the reaction neutral, and the water odorless, and this is the presumption in the case of other sanitary analyses. Profs. F. S. and R. C. Kedzie jointly furnished me with a list of analyses, the credit for which belongs sometimes to one and sometimes to the other.

Carbonates and bicarbonates are entered in the same place in the tables, the latter preceded by bi. It may be useful to say that the ratio of carbonate to bicarbonate for a given amount of the base found is: For lime, 100:162.02; for magnesia, 84.36:146.38; for iron (FeO), 116:178.02; for soda, 106.10:168.12. In a rough way, there is half as much again when the compound is given as bicarbonate as when it is given as carbonate.

WATERS OF THE GREAT LAKES SYSTEM.[1]

Constituent.	1. Manistee Lake.	2. Muskegon Lake.	3. Traverse Bay.	4. Detroit River.	5. Detroit River.
Al_2O_3					0.0105
$CaCO_3$	*5.898* .101	*4.882* .084	*3.412* .058	*3.144* .054	.033
CaP_2O_8					.0311
$CaSO_4$	Tr.	*1.660* .028	*1.793* .031	*.664* .011	
$(FeAl)_2O_3$	Tr.	*.029* .001	Tr.	Tr.	
$FeCO_3$					.00814
$MgCO_3$	*2.345* .040	*2.654* .046	*2.013* .034	*1.203* .021	
K_2SO_4					.00283
SiO_2	*.292* .005	*.292* .005	*.215* .004	*.350* .006	.005
(NaK)Cl	*5.100* .087	*1.02* .017	*.680* .012	*.900* .015	
$(NaK)_2CO_3$	*.147* .003	*.209* .004	*.764* .013	*.045* .001	
Na_2SO_4					.0075
Organic matter			*.467* .008		
Total	*13.782* .236	*10.746* .185	*9.344* .160	*6.306* .108	.09807

[1] Analyses are given in grams per kilogram, or parts per thousand. Numbers in italic are quantities expressed in the units in which the analyses were originally published, usually, as in the first table, in grains per United States gallon.

Constituent.	6. Detroit River (A).	7. Detroit River (B).	8. Detroit River (C).	9. Bay City (A).	10. Bay City (B).	11. Bay City (C).	12. Saginaw Bay.
CaO	0.0355	0.0360	0.0348	0.079072	0.116928	0.105952	0.031136
P_2O_5	0	Tr.	0	.....	.....	.....	.....
SO_3	.0056	.0060	.0056	.....	.....	.....	.....
MgO	.0121	.0127	.0123	.030558	.049874	.053333	.016432
SiO_2	.0066	.0062	.0089	.....	.....	.....	.....
Cl	.....	.....	.0075	.058	.265	.284	.010
Total	.1188	.1184	.1140	.....	.....	.....	.....

Analyses 1 to 4 were made by commercial chemists of the Dearborn Drug and Chemical Works, of Chicago. Their primary purpose was to determine quality as boiler waters; they were stated in grains per United States gallon; they did not aim at completeness, and no summation was given in the original analysis.

No. 1, of water from Manistee Lake, was made for Filer & Sons, August 31, 1897. The water was probably contaminated by the large salt works there.

No. 2, of water from Muskegon Lake, was made for the Electric Light Company, November 23, 1897.

No. 3, of water from Traverse Bay, was made for the electric light works of H. D. Campbell & Sons, August 31, 1897. Further analyses will be found in the Appendix (2A, 2B, 2C). It will be noticed, on comparing them with the deep-well water supply, analyses Nos. 56 and 57, that the bay water is considerably less hard. Of course it is more liable to typhoid contamination.

No. 4, of water from Detroit River, was made January 22, 1897, for the Schiller Corset Company.

No. 5 is an old analysis, made by Prof. S. H. Douglass in 1854, and cited in the biennial report of the State geologist, A. Winchell, in 1861, page 204. The total solids agree with other analyses, but the phosphates and sulphates are quite different, though some phosphorus is probably often overlooked.

Nos. 6 to 12 were made by Prof. A. B. Prescott, Nos. 6 to 8, of water from Detroit River, in conjunction with T. J. Wrampelmier, for the Detroit board of health (First Annual Report, 1882, pp. 229–238). Further analyses will be found in the Appendix (Nos. 5A, 6A, 7A).

No. 6 is of water from a West Fort street hydrant at Detroit; No. 7 of water from the pumping well, and No. 8 of water from the river at the inlet pipe of the Detroit pumping station.

Nos. 9 to 12 were published in a special report to the board of waterworks of Bay City, October 24, 1885, the waters of Nos. 9 to 11 being taken from manholes Nos. 4, 2, and 1, respectively, in the pipe leading from the pumping station on the bay shore to Essexville. One object of the investigation was to see if the water was contaminated in the transit by any waste of salt manufacture.

Sample No. 12 was taken about 2 miles north from the mouth of Kawkawlin River, and 1½ miles from the west shore of the bay, in water 16 feet deep, September 27. This also contained 0.04 per million parts of free ammonia and 0.15 of albuminoid; it reduced permanganate very slightly, was colorless and odorless, as were all the samples, but the residue blackened slightly on ignition.

Analyses of water from Saginaw Bay near Bay City.

	13.	14.	15.	16.	17.	18.
Ammonia free	0.00007	0.00016	0.00005	0.00007	0.00004	0.00008
Ammonia albuminoid	.00011	.00012	.00008	.00017	.00022	.00016
Permanganate reduced	2	1	4	7	8	3
Color	Colorless.	Colorless.	Nearly colorless.	Slight.	Perceptible.	Distinct.
Chlorine	.012	.010	.029	.072	.072	.039

	19.	20.	21.	22.	23.	24.
Ammonia free	0.00007	0.00004	0.00002	0.00003	0.00005	0.00004
Ammonia albuminoid	.00016	.00022	.00007	.00024	.00024	.00012
Permanganate reduced	6	2	6	3	7	1
Color	Distinct.	Slight.	Very slight.	Slight.	Distinct.	Colorless.
Chlorine	.235	.226	.221	.200	.061	.010

Besides analyses Nos. 9 to 12 and the Saginaw River analysis (No. 45) below, Professor Prescott made a number of tests for ammonia, free and albuminoid, and chlorine (analyses Nos. 13 to 24). Prescott pronounced the waters of analyses Nos. 12, 13, 14, 24, which are all taken from Saginaw Bay, more than a mile from the shore and in water over 10 feet deep, to be suitable for city use. Analyses Nos. 19 to 22, of water taken from the waterworks system, are not satisfactory, the organic matter being on the limit of safety, and the chlorine, which is probably not, however, of organic origin, far too high. These should be compared with analyses Nos. 32 and 33, of water from the same system, made by Prof. V. C. Vaughan. Samples Nos. 15, 16, 17, 18, and 23, taken from the bay nearer the pumping station and the shore, are not quite satisfactory, and though they contain less chlorine the quantity is still abnormally large, while Saginaw River water No. 45, West Bay City waterworks, is entirely unfit for use. The exact locations from which the waters of these analyses were taken are as follows:

No. 13, about 1 mile NNW. from the mouth of the Kawkawlin River, in water 11 feet deep, July 23, 1885.

No. 14, about 4 miles NE. from the mouth of the Saginaw River, in water 21 feet deep, July 24, 1885.

No. 15, about 3¼ miles E. from the mouth of the Saginaw River and 1 mile N. from the present inlet works, in water 10 feet deep, July 23, 1885.

No. 16, inlet cut of the present works at the outer end of breakwater, July 23, 1885.

No. 17, the inlet basin at the bay, at the outer end of the pipe leading to the pumping station, July 23, 1885.

No. 18, same point as sample No. 17, August 11, 1885; turned very black on ignition.

No. 19, well at pumping station, inner end of pipe leading from the bay, August 11, 1885.

No. 20, hydrant near the corner of Fourth and Water streets, August 14, 1885.

No. 21, hydrant near the corner of McGraw avenue and Harrison street, August 14, 1885.

No. 22, same point as sample No. 20, but when there was a large quantity of sediment from flushing the pipes; sample taken August 22, 1885.

No. 23, a point 3,000 feet NNE. from the present inlet basin, in water 7½ feet deep, September 25, 1885.

No. 24, a point 5,500 feet NNE, from the present inlet basin, in water 10½ feet deep, September 25, 1885; blackened slightly on ignition.

	25. Detroit.	26. Marine City.	27. Port Huron.	28. Port Huron.	29. Port Huron.	30. Alpena.	31. Wyandotte.	32. Bay City.	33. Bay City.
Result of inoculation	−	+	+	+	−	+	+	−	+
Number of bacteria in 72 hours	2	(a)	(a)	(a)	(a)	22	1,890	420	450
Nitrites	.....	Ft. tr.	.....	.....	.....	.....	0.0000082	.....	.....
Nitrates	.....	Tr.	Tr.	Tr.	Tr.	.....	.000653	.....	.....
Albuminoid ammonia	0.000102	0.00112	0.000120	0.000132	0.000126	0.00037	.00052	0.00048	0.00068
Free ammonia	.000016	.0001	.000009	.000007	.000006	.00048	.00008	.00034	.001
Permanganate reduced	.....	.....	.....	.....	.....	.008104	.032548	.063832	.106176
Chlorine as NaCl	.00115	.00990	.00830	.0099	.00825	.0066	.0495	.4257	.4653
Organic residue	.020	.110	.040	.070	.030	.025	.030	1.210	.980
Inorganic residue	.030	.043	.120	.150	.040	.162	.191	1.960	1.990
Total residue	.050	.153	.160	.220	.070	.187	.221	3.170	2.970
Hardness	.7°	4.°	2.°	2.1°	2.°	8.10°	7.°	15.°	15.5°
Sulphates	.....	.....	Tr.	Tr.	Ft. tr.	.....	.....	.....	.....

a Liquefaction.

Analyses 25 to 33 are sanitary analyses by Prof. V. C. Vaughan, made at Ann Arbor. The dates and the original numbers (in parentheses), the results of microscopic examination, etc., are as follows:

No. 25 (259), April 19, 1895, water said to be from the bay, i. e., the upper part of the Detroit River (?); reaction faintly alkaline; this is

exceptionally low in solids, though it checks in chlorine fairly well with analysis No. 4.

No. 26 (230), August 21, 1894; water "musty alkaline, microscope shows nematoid worms, ova, vegetable débris, desmids, diatoms, infusoria, bacteria."

No. 27 (255). This and the two following analyses form a set of three, dated by Professor Vaughan March 3, 1895. At the waterworks I was told that Professor Kedzie made a set of three analyses, which had been lost—one of the river water above town, one of the river water below the town, and one of water 12 miles out on Lake Huron. I suspect that these are the analyses referred to, and that No. 27 is of water at the town, No. 28 of water from St. Clair River below the town, and No. 29, which is much more free from organic matter, is the one of water from out on Lake Huron. No. 27 (255) was milky colored (in 1897 when I visited the plant the water was slightly turbid from clay dredging), smelled musty, gave an alkaline reaction, and the microscope showed wood fiber, algæ, unicellular plants and animals, inorganic deposits, and much vegetable débris. On November 3, 1892, a test (165) showed granular sediment 7.3° hardness, 0.002 chlorides, 0.00007 free and 0.00012 albuminoid ammonia, 5,840 bacteria in seventy-two hours, and no inoculation effect.

No. 28 (256), also milky colored, musty, alkaline, with algæ, wood fiber, inorganic deposits, much vegetable débris, unicellular plants and animals.

No. 29 (257), also milky, musty, alkaline, with wood fiber, algæ, unicellular plants and animals, vegetable débris, inorganic deposits.

No. 30 (81), taken from the hydrant at Alpena (a town using Lake Huron water), June 10, 1890; microscope shows fresh-water algæ, white amorphous material, red spores of algæ, streptococci, oscillators, and bacilli; the extreme hardness reminds one that limestone crops out abundantly around Alpena.

No. 31 (93) Wyandotte waterworks, November 12, 1890. These works draw water from the Detroit River below Detroit, and there has been considerable complaint as to the prevalence of typhoid fever. At 100 diameters magnification crystals, algæ, and yellow and white amorphous matter are visible; at 500 diameters, crystals of NaCl, silica, fibers, algæ, Vorticellæ, yellow and white amorphous matter.

No. 32 (90) from Bay City hydrant, November 4, 1890; not clear, smells slightly fishy. Under 100 diameters the microscope shows diatoms, algæ, animalculæ, fibers; under 500 diameters, Navicula, Paramecia, Pinnula, Conferva.

No. 33 is a duplicate, same source and time and similar, but also shows desmids and Volvox. These two analyses are directly comparable with Prescott's analyses, Nos. 19 to 22, and show a similar large amount of chlorine.

It will be noticed that, while the water of the Great Lakes is not so hard as many of the waters described later, it is usually charged

with more $CaCO_3$ than can be taken up without an excess of CO_2, viz, more than 0.034 ounce per cubic foot. The effect of the salt industry in charging the shallow Saginaw Bay with chlorides is well brought out, the normal amount of salt being probably 0.010 to 0.007. The effect of the salt industry of Manistee seems also to be traceable in the chlorides of Manistee Lake.

THE WATER OF LAKE SUPERIOR.

As none of the analyses given above were exhaustive and none were made with extreme care, it seems worth while, especially in connection with the question of the distribution of the rarer elements, to add the following analysis of Lake Superior water (No. 34) made in 1887 by W. F. Jackman, then a student in the University of Michigan, now professor of pharmaceutical chemistry in Maine State College, Orono, Me.[1]

The sample for analysis was obtained during the summer of 1886, by Captain Mooney, of the steamship *India*, about 50 miles from Keweenaw Point, at a depth of 50 feet, and was sent to the university laboratory in a large carboy. There was also secured at the same time with this sample a sample from Lake Huron, which it is regretted certain considerations compelled to be laid aside unexamined.

The analysis of the sample of Lake Superior water was not made until the latter part of December and first of January following its collection. Although the carboy contained over 18 liters of water, yet the small amount of inorganic solids (only 57.61 milligrams per liter) rendered this seemingly large amount of water really small for all the necessary estimations and duplicates, so that economizing of material had to be studied from the very first.

Among the precautionary methods employed was the frequent use of ammonium fluoride (in platinum crucible) after the usual final weight taken in gravimetric work—the whole thing being then reweighed, and this last weight taken as the true one—the first weight being simply a check.

With the fact of the slight solvent action on glass or porcelain of large quantities of boiling liquids—even of distilled water—all are familiar; but this is generally ignored as an insignificant amount. That it really becomes an important factor in work such as the present (involving large quantities of water with very small residues) Thorpe, Fresenius, and others have shown by definite experiments. In the present work the correction necessary from this cause was generally inconsiderable, but not always; e. g., in determinations of magnesium one sample, weighed as magnesium pyrophosphate, gave 48.3 milligrams before ignition with ammonium fluoride, while after such ignition it weighed only 41.6 milligrams, a loss of 6.7 milligrams. Another sample of magnesium pyrophosphate lost 5.2 milligrams, in both cases from 3 liters of water. Of course care was taken that loss did not occur from the crucible being uncovered or from spurting through sudden applications of heat, etc. In estimation of sulphuric acid (as barium sulphate) after ignition, to expel slight excess of ammonium fluoride and the silicon fluoride formed, the residue was treated with a drop of sulphuric acid and reignited. In the case of alumina and ferric oxide estimation there is generally present a small amount of silica which has escaped separation in its usual place; hence the silica found here was added to the total silica obtained in the regular estimation of that constituent. This silica found with alumina and ferric oxide may properly be thus regarded as wholly belonging to the total silica of the sample, as very little liquid is operated on after

[1] Proc. Mich. Pharmaceutical Association, fifth year, p. 110.

the regular separation of silica before the separation of alumina and ferric oxide take place.

Evaporation was carried on in broad, shallow, ½-liter porcelain dishes, covered with a funnel of special design with an incurved rim, made to set snugly (but unfortunately not air tight) upon the rim of the evaporating dish.

I say unfortunately not air tight, for Mallet has shown that the flame of the Bunsen burner in time produces quite appreciable amounts (when fine work is considered) of $(NH_4)_2SO_4$ and that unless the evaporating dish is kept tightly covered, danger of error from this cause is likely to occur. (See Mallet's Report on Water Analysis in the Report of National Board of Health, 1882, p. 194, where he shows that nitrogen determinations by Frankland's combustion process, as ordinarily conducted, give too high results from this cause.) Mention of this is made here only to indicate that this might possibly somewhat affect the determination of sulphuric acid.

To the nozzle of the funnel was attached a rubber tube connected with a water section pipe. This served to create a rarefaction above the evaporating water, thereby increasing the rate of evaporation and permitting the use of the lower temperature. Any steam failing to pass off through the pump because of condensation on sides of the funnel could not run back into the dish, but was caught by the incurved rim of the funnel. Extraneous particles of dust, etc., were also thus excluded. When total solids were to be estimated evaporation was in no case continued to dryness; but the liquid concentrated to about 200 cubic centimeters was carefully transferred in portions to a large platinum evaporating dish, with subsequent thorough rinsing with distilled water, the whole evaporated to dryness, dried in the air bath at 100° C. for three hours, cooled in a desiccator over sulphuric acid, and weighed for total solids. Five such determinations were made. The residue was ignited at low red heat for about two hours to constant weight, cooled, and weighed as total inorganic solids. In a few cases this latter residue was treated with $(NH_4)_2CO_3$ in solution, reheated, and weighed again; but the increase averaging only 0.6 milligrams per liter, this operation was subsequently neglected, although account was taken of it in final results.

One and one-half liters were concentrated by evaporation, transferred to platinum dish and evaporated to dryness, weighed, ignited, and weighed again, as described above, for total solids and inorganic solids. The residue was then examined qualitatively, by the usual methods, with good tests resulting for Al, Fe, Ca, Sr, and Mg (rather fainter test). The flame test showed Na but no K, which occasioned some surprise. Through the kindness of Prof. L. W. Langley, the aid of his spectroscope and his personal assistance were secured to identify any of the rarer metals that might be present—it being thought that Li at least might be present; but nothing was found that had not been already identified, except that faint, evanescent flashes of K were seen.

Thinking that previous estimation of total solids and consequent protracted ignition of this sample might possibly have affected the spectroscopic result somewhat, two or three fresh trials were made on concentrated solutions before full evaporation, but with no different results.

Pb was tested for in a large 8-inch test tube full of the sample (after acidulation with 1 to 2 drops of acetic acid) by addition of a drop of solution of $K_2Cr_2O_7$ with no result. Cu was tested for in a similar manner with 1 to 2 drops of solution of K_4FeCy_6 and allowed to stand over night, when a very faint green or greenish-blue tint was apparent, evidently due to Fe only. Mn was tested for by PbO_2 and HNO_3 (in concentrated solution), with no result.

Fair tests for HCl and H_2SO_4 were obtained. Cl water and CS_2 showed scarcely definable traces of Br, and $(NH_4)_2MO_4$ in HNO_3 solution gave no distinguishable trace of H_3PO_4, and no I nor TiO_2 was found, all, of course, worked for from concentrated solutions. Most, if not all, nitrates and nitrites would have been destroyed

by ignition in presence of organic matter and were therefore not looked for at this point. (See under quantitative work.) In reference to the comparatively few elements found, it is to be remembered that different results might reasonably have been expected could larger quantities of the water have been spared for such work.

For quantitative work in each case 3 liters were taken and evaporated to dryness, after acidulation with HCl and SiO_2, separated in the usual way, with care against high heating and consequent danger of partial reunion of separated SiO_2 with the bases. Fe_2O_3 and Al_2O_3 were precipitated from the filtrate by boiling with fair excess of HH_4OH (in presence of NH_4Cl) and the united oxides weighed. The Fe was subsequently subtracted, after volumetric estimation by Oudemans' method (i. e., by $\frac{n}{10}$ $Na_2S_2O_3$ in presence of $CuSO_4$, with a drop of KCyS as indicator) and also by the excellent method described in Professor Cheever's Laboratory Notes (Part I, p. 27, and Part II, p. 6), by reducing Fe_2Cl_6 to $FeCl_2$ in boiling HCl solution, by means of $SnCl_2$ carefully added from burette, and any excess of $SnCl_2$ taken up with $HgCl_2$ and the $FeCl_2$ titrated with $\frac{n}{10}$ $K_2Cr_2O_7$. Al and Fe were also directly separated by pouring into boiling KOH in excess, after the method of Fresenius.

Ca and Sr were precipitated together from the filtrate from Fe and Al by addition of $(NH_4)_2C_2O_4$ and $(NH_4)_2CO_3$, the combined precipitates carefully heated in platinum crucible by playing back and forth underneath a small flame and carefully noting the change in color of the precipitates. After thus working to constant weight, the residue was tested with a bit of moistened turmeric paper to see that no reduction to oxides had occurred.

The Ca and Sr were then separated by the method of H. Rose (given by Fresenius) by precipitating with $(NH_4)_2SO_4$, filtering hot, and continued washing with concentrated solution of $(NH_4)_2SO_4$ until filtrate showed no test with $(NH_4)_2C_2O_4$. This filtrate after concentration was reworked for Ca by reprecipitation with $(NH_4)_2C_2O_4$. The Sr was treated similarly to $BaSO_4$ and weighed as $SrSO_4$. After weighing Ca as $CaCO_3$, in addition to the precautions mentioned above, the precipitate was in each case dissolved in excess of boiling $\frac{n}{10}$ H_2SO_4, to expel CO_2, and the excess of H_2SO_4 neutralized by $\frac{n}{r}$ KOH, with phenol phthalein as indicator, and Ca recalculated as a check.

Mg was precipitated from the filtrate from Ca and Sr in the usual way, as NH_4MgPO_4 and weighed as $Mg_2P_2O_7$. Double precipitation of the Ca and Sr was performed in each case to insure separation of Mg.

One liter was taken in each case, and the Na separated and weighed as NaCl, and then dissolved in water, and the Cl estimated with standard solution $AgNO_3$, and Na recalculated. The method for separation followed is the one used for separation of K, recommended by the Association of Official Agricultural Chemists, 1886 (Dept. Agriculture, Div. Chem., Bull. No. 12). The principle is familiar, i. e., the removal of bases and H_2SO_4 by boiling with $Ba(OH)_2$ and a little $BaCl_2$, filtering, and removing Ca by $(NH_4)_2C_2O_4$ and the excess of $BaCl_2$ by $(NH_4)_2CO_3$, the evaporated residue ignited, dissolved, filtered, acidulated with a drop of HCl, ignited, and weighed as NaCl, and treated as above. Great care and practice seem essential to obtain anything like closely concordant results. In the following table, because of considerable divergence in the gravimetric results, only the volumetric results are considered, the average of all being taken. That appreciable quantities of NaCl may be lost by several minutes' ignition at red heat is shown by Fresenius's experiments.

H_2SO_4. The precipitate in the preceding results for Na (thrown down by $Ba(OH)_2$ and $BaCl_2$) was treated with HCl in excess in hot solution, thoroughly washed and treated as usual for $BaSO_4$.

HCl. One-half to one-fourth liter was concentrated to about 100 cubic centimeters and the Cl estimated by $AgNO_3$, with K_2CrO_4 as indicator. Two strengths of the solu-

tion of $AgNO_3$ were tried; No. 1, 1 cubic centimeter of the solution = 1 milligram Cl; and No. 2, 1 cubic centimeter of the solution = 0.1 milligram Cl.

Combined CO_2. 250 cubic centimeters was concentrated to about 100 cubic centimeters, and moderate excesses of $\frac{n}{10}$ H_4SO_4 run in from burette, and the solution was boiled to free it from CO_2. Then excess of acid was neutralized with $\frac{n}{10}$ KOH with phenol phthalein as indicator. Fresenius recommends HNO_3 with tincture cochineal indicator; but probably through inexperience in its use the results were not thought to be so satisfactory as the method mentioned above. I am aware that the method adopted is open to very serious objections, not the least of which is the danger of loss of HCl and HNO_3 on boiling to expel CO_2. It was attempted to avoid this and the consequent higher results as much as possible by working to get the approximate point with the standard alkali with turmeric indicator before boiling, and then finishing in the usual way. It will be observed that if all the HCl and HNO_3 were lost it would increase the reading for CO_2 about 1.7 milligrams per liter. It would, on the whole, perhaps have been better to have used the theoretically much better method of liberating the CO_2 by acidulation in closed flasks and absorbing the CO_2 in KOH bulbs or standard $Ba(OH)_2$ solution by Pettenkofer's method. This was not tried, however, from fear of loss in transferring from evaporating dish to flask.

The specific gravity of the dish of water was taken by the spherical specific-gravity bottle used in this laboratory, and both distilled water and the sample were brought to 27° C. before filling the bottle.

In the following table all the results are the average of results obtained and in no case the result of a single estimation.

All results are given in parts per million; or, what is the same thing, milligrams per liter.

34. Lake Superior water.

Specific gravity (at 27° C)	1.0004
Total residue	69.97
Inorganic residue	57.61
Loss on ignition	12.36
Organic determinations:	
Free ammonia	.061
Albuminoid ammonia	.12
Oxygen consumed	1.77
Hardness:	
Temporary	a 48.57
Permanent	a 38.28

Inorganic constituents:

Al_2O_3	= 0.90	Al	= .48
Fe_2O_3	= 0.99	Fe	= .69
CaO	= 17.98	Ca	= 12.80
SrO	= 1.60	Sr	= 1.34
MgO	= 4.63	Mg	= 2.78
Na_2O	= 4.29	Na	= 3.18
K_2O	Very faint trace.	K	Very faint trace.
SO_3	= 3.11	SO_4	= 8.73
SiO_2	= 6.73	SiO_2	= 8.53
B_2	Trace.	B_2	Trace.
Cl	= 2.43	Cl	= 2.43
N_2O_4	= 0.00	.....	
N_2O_5	= 0.67	N_2O_5	= .77
CO_2	= 16.30	CO_2	= $\frac{22.23}{58.96}$

The purpose of this second set of figures, with bases reported as free elements and the acids as acid radicals, is that the total results thus obtained may be compared with the inorganic residue.

a In parts per million, not in degrees.

WATERS OF RIVERS AND SMALL LAKES.

Constituent.	35. Battle Creek.	36. Owosso.	37. Jackson.	38. Ann Arbor.	39. Shiawassee.	40. Cass.	41. Chippewa.
$CaCO_3$	*5.679*	*6.041*	*8.652*	*7.495*	0.1090	0.1130	0.1314
	.063	.103	.148	.128			
$CaSO_4$	*1.494*	*1.394*	*2.490*	*5.810*			.0316
	.025	.024	.043	.099			
$(AlFe)_2O_3$	Tr.	*.058*	Tr.	Tr.	.0061	.0070	.0094
		.001					
$MgCO_3$	*2.853*	*5.015*	*4.264*	*4.866*	.1789	.03322	
	.049	.086	.073	.083			
$MgSO_4$					.0369	.0309	
$(NaK)_2CO_3$	*1.770*	*1.228*	*.376*	*1.453*			
	.030	.021	.006	.025			
(NaK)Cl	*1.090*	*1.360*	*1.200*	*.900*	.0231	.02405	.0504
	.017	.023	.021	.015			
SiO_2	*.380*	*.438*	*.537*	*1.343*	.0691	.0470	.0140
	.007	.007	.009	.023			
P_2O_5					Tr.		
Ammonia, free					.00011	.00015	
Ammonia albuminoid					.00054	.00054	
Organic and volatile.	*.818*	*.818*		*.818*			
	.014	.014	Tr.	.014			
Total	*12.014*	*16.362*	*17.519*	*22.685*	*a* .423	*a* .2552	.2360
	.205	.279	.300	.387			
Hardness					16.6°	7.5°	
Chlorine					.0140	.0146	

a Inorganic.

Constituent.	42. Saginaw W.	43. Saginaw E.	44. Tittabawassee.	45. Bay City.
$CaCO_3$	0.134	0.11057	0.138	
CaO				0.78624
$CaSO_4$		.01788	.04008	
$(FeAl)_2O_3$	.007	.0611	.0843	
$MgCO_3$	.04678			
MgO				.36468
$MgSO_4$	.02968	.01944	.0084	
SiO_2	.028	.078	.1092	
NaCl	.0814	.0581	.0444	
P_2O_5	Tr.	Tr.	Tr.	

Constituent.	42. Saginaw W.	43. Saginaw E.	44. Tittabawassee.	45. Bay City.
Ammonia, free	0.00048	0.000104	0.000256	Tr.
Ammonia albuminoid	.00043	.000350	.000440	0.00025
Total inorganic	.32686	.34509	.42438	
Hardness	10.5°	6.4°	8.0°	
Chlorine	.0494	.0372	.027	.072

Analyses 35A and 35B in the Appendix are of water from Boardman River near Traverse City, the former made by R. C. Kedzie and the latter by the Dearborn Drug and Chemical Works, and they agree in indicating a relatively soft water.

Analyses Nos. 35 to 38 are boiler-water analyses made by the Dearborn Drug and Chemical Works, of Chicago.

No. 35 is of the Battle Creek city water supply, which is usually obtained from Lake Goguac, and was made for the Advance Thresher Company on August 6, 1897.

No. 36 is of water from the Shiawassee River at Owosso, and was made for the Estey Manufacturing Company, factory A, on October 30, 1897; there is less matter in solution at Owosso than farther down the river, as shown by No. 39.

No. 37 is of water from the Grand River at Jackson, and was made for the Withington-Cooley Manufacturing Company on February 11, 1897.

No. 38 is of water from the creek at Ann Arbor (? the Huron River), and was made for the Ann Arbor Electric Company.

Analyses Nos. 39, 40, 42, 43, and 44 were made by G. A. Kirchmaier for the board of water commissioners of the city of Saginaw, and were published in the supplement to the annual report of that board for 1892, pages 31–33.

No. 39 is of water from the Shiawassee River.

No. 40 is of water from the Cass River.

No. 41 was made by J. E. Graves, of the Dow Chemical Company; the sample was taken from the Midland water supply (Chippewa River) on July 27, 1896. This analysis is very like analysis No. 44, of water from the Tittabawassee River.

No. 42 is of water from the west-side pumping station, Saginaw, and its thoroughly unsatisfactory condition will be treated in a later paper. The chlorine, 0.0494, is the highest of the set.

No. 43 is of water from the east-side pumping station, Saginaw.

Analyses 43A to 43D, made by H. and W. Heim for S. G. Higgins, show the composition of Saginaw River water at various places and the increase in NaCl and organic residue. The impurities in the water increase downstream. On the whole the magnesia and lime also increase, although quite irregularly.

No. 44 is of water from the Tittabawassee River.

No. 45 is of water from the Saginaw River at Bay City, and was made by Prof. A. B. Prescott at the same time as the analyses of the Bay City supply (Nos. 13 to 24), namely in July, 1885. The sudden increase in CaO and chlorides together is due to contamination by the waste bitterns of salt manufacture. The Marshall sandstone yields brines with considerable calcium chloride. The amount of lime carbonate does not increase with the general increase in mineral matter, but shows a strong tendency to stick at about one-tenth of an ounce per cubic foot, which is enough to indicate the presence of bicarbonates. Sulphates of lime are almost invariably present, though the sulphate is sometimes returned only as sulphate of magnesia. Throughout the coal basin and southwest of it this salt is very prevalent both in wells and streams.

Ten analyses, by college students, of water from a brook near the Agricultural College (analysis No. 36A in the Appendix) give, as an average result, a much softer water than most of the stream waters analyzed. The sample was probably taken after a rain.

A series of twenty-two analyses of waters from marl-depositing and other lakes, wells, and outlet streams, collected by D. J. Hale, near

Cloverdale, Barry County, were made by A. N. Clark. The $MgCO_3$ is usually between 0.065 and 0.085 parts per thousand, the extremes being 0.203 and trace. The amount of $CaCO_3$ is more variable, being as high as 0.217 and never less than 0.030. As much as 0.066 of free CO_2 was sometimes found, supposed to be in addition to that present as bicarbonate.

	46. Cadillac.	47. Battle Creek.	48. Mancelona.	49. St. Louis.	50. Wayne.	51. Wayne.
Result of inoculation	−	−	+		−	−
Number of bacteria in 24 hours	100	Countless.	76	1,088		
Nitrites						0.000026
Nitrates	Tr.		Tr.			.000016
Albuminoid ammonia	0.0000528	0.00022	0.0000533	0.00032		
Free ammonia	Tr.	.00015	.000013	.000046		
Permanganate reduced			26			
Chlorine as NaCl	.00066	.028	.0083			.033
Organic residue	.040	.080	.288			
Inorganic residue	.060	.100	.246			
Total residue	.100	.180	.534			
Hardness	4.0°	10.2°	14.3°	14.4°		

Analyses Nos. 46 to 51 are sanitary analyses by Prof. V. C. Vaughan, of Ann Arbor, and are in general subject to the same remarks and interpretation as the others (see p. 44).

No. 46 (193), water from Clam Lake near Cadillac, July 29, 1893; brownish, musty; microscope shows vegetable fibers and a few forms of animal life.

No 47 (294), water from a Battle Creek hydrant; reacts alkaline, and under the microscope shows diatoms and inorganic matter.

No. 48 (345), water from a lake in Mancelona, T. 29 N., R. 6 W., November 17, 1896. The water is reddish brown in color, has a marked odor and acid relation, and under the microscope shows the presence of considerable vegetable matter.

No. 49 (35), water from the Pine River at St. Louis; contained no pathogenic germs.

No. 50 (372), water described as "cloudy, stinking," and No. 51 (373), were tests of Huron River water and the overflow of the settling basins of the Wayne County poorhouse, October 25, 1897.

WATERS FROM WELLS IN THE UNCONSOLIDATED DEPOSITS (PLEISTOCENE) AND FROM SPRINGS.

This group includes those waters which have penetrated in their circulation but a little way under ground. All the common dug wells belong to this class, and probably a very large portion of the waters of the unclassified analyses given in a later section.

The Michigan board of health has issued a plate showing the relation that the depth of water in wells bears to the prevalence of typhoid

fever during the different months of the year. From April to June the water in the wells is, on an average, within 200 inches of the surface of the ground, and typhoid fever is least common. By October the average water level has fallen over 30 inches, and typhoid fever is most prevalent.

I begin with analyses which show only a small proportion of mineral matter—considerably less than 1 ounce to the cubic foot—and which may be classed as pure drinking waters, soft or slightly hard. Some of these waters are reputed to have curative powers, but none have any mineral taste, and it is probable, as the proprietor of the Ponce de Leon spring remarks, that their virtue lies mainly in their purity.

As the percentage of mineral matter increases the waters, almost without exception, become hard, and are comparable to the river waters in lime (one-tenth to two-tenths of an ounce per cubic foot), but contain more iron and silica than the latter. In these more mineralized waters some of the apparent variety in the chemical combinations seems to be due to the fancy of the chemist—for instance, the presence of sulphate of potash in some and of carbonate of potash in others of the Benton Harbor Eastman springs. Analyses by Duffield are particularly unusual in the combinations assumed.

It will be noticed on comparing the deeper and shallower wells at Traverse City (Nos. 56 and 57), at Holland (Nos. 147 and 159), and at Ypsilanti (Nos. 70 and 71), that no tendency is seen toward a greater mineralization with depth—the rule which prevails among wells in the rock. It is probable that a careful study would show a zone close to the surface, a foot to a few feet down, from which the lime had been removed by leaching, for at Mecosta and other places I have found very shallow, easily exhausted wells used for laundry purposes. Then just below this would be a belt in which the lime and iron had been deposited as a cement in extra richness, while lower down would be found waters of the unaltered drift.

Finally, there is a group of waters (analyses Nos. 73 to 80) which are strongly sulphated, and, with the exception of the Detroit well, come from the same region, a region in which gypsum bowlders have been found scattered in the drift. The exception (No. 76) has more salt than the others, and is more like a weak brine. Near Marine City, on the farm of Mrs. E. Gardner, there is a well of which no complete analysis of the water is available, but which is said to contain, out of a thousand grains per gallon solids, more than half $MgSO_4$ (Epsom salts). Such sulphated waters may be due either to the solution of gypsum or to the production of sulphuric acid or sulphates by the decomposition of pyrite, which is abundant in the drift and in the rock, and their subsequent reaction upon carbonates or chlorides.

The wholesomeness of these sulphated waters depends largely on the individual constitution. Professor Kedzie condemned waters from Mount Pleasant as too high in sulphates (and I should agree with him) which Professor Vaughan passed as good because free from dangerous

organic contamination. I find, however, that in such regions some doctors complain of the prevalence of indigestion, constipation, and calculi.

Belonging to the group of highly sulphated mineralized waters from the drift of the center of the State are probably some of the analyses by Kedzie of waters around Saginaw (Nos. 108 to 110), but as some of those wells penetrate a few feet into the top sandstone, and as others draw their water from a bed immediately overlying it, I have deemed it better to treat them in the next section, since it is not certain how far wells in the drift only are mineralized under that city. For example, the well at 905 Court street, East Saginaw, about 80 feet deep, gave in the analysis of Dr. Small only 6.5 grains to 1 liter, or 0.421 part to a thousand solids, with a faint Cl reaction. The two Midland waters (analyses Nos. 75 and 77) are in practically the same class.

Constituent.	52. Ponce de Leon spring.	53. Harbor Springs.	54. Greenville.	55. Ann Arbor (University).	56. Traverse City High School.	57. Traverse City (Asylum).	58. Pontiac.
Al_2O_3							*0.0806* .0014
$CaCO_3$	*7.2* .12312	*8.50* .121	*9.63* .136	0.178	0.128	*9.758* .167	*9.6807* .1660
$CaSO_4$	Tr.		0		.002	*1.328* .026	
Fe_2O_3		*.50* .007			.003	*.298* .005	*.5025* .0086
$FeCO_3$				.0029			
Li_2CO_3							*.0200* .0003
$MgCO_3$		*1.50* .021	*3.175* .045	.06058	.034	*4.004* .068	*3.9159* .0672
KCl							*.06990* .0012
K_2SO_4				.00678			
SiO_2		*1.00* .014		.0073	.006	*1.997* .034	*.4082* .0070
NaCl	Tr.	*.50* .007	0	.00448	.006	Tr.	*.3090* .0053
Na_2CO_3				.00152		*a .602* .010	*.2916* .0050
Na_2SO_4				.00507			*.2799* .0048
Nitric acid			*.207*				
Free CO_2			.003	.0015598			
Organic	*1.75* .030	*1.50* .021	0	.0023	.014		*c .9244* .0158
Total	*8.959* .153564	*13.00* .183	*13.25* .189	.28963	.198	*17.987* .307	*16.4827* .2826
Total hardness	7.2°	11.°			12.°		
Permanent hardness		5.°			6.°		
Free ammonia			.000052		.00015		
Albuminoid ammonia			.000003		.00008		

a CNa or K. *b* Oxygen reduced by permanganate. *c* Loss.

Constituent.	59. "King David," Benton Harbor.	60. "Silver Queen," Benton Harbor.	61. "Saul," Benton Harbor.	62. "Colonel's Own," Benton Harbor.	63. Springs, Petoskey.	64. "Park," Alma.	65. "Nochemo," Reed City.
Al_2O_3	*0.117* .0020						0.001
$CaCO_3$	bi. *8.124* .1390	bi. *6.800* .1165	bi. *7.797* .1336	bi. *8.835* .1520	*12.32* .176	0.188	bi. .203
Fe_2O_3				*.234* (*a*). 00402	*.14* .002		0.03
$FeCO_3$	bi. *1.298* .0223		bi. *1.049* .018			.106	.003
$MgCO_3$	bi. *3.532* .0605	bi. *3.225* .0553	bi. *6.144* .1052	bi. *6.296* .1078	*2.80* .040	.041	bi. .110
P_2O_5	Well-marked traces.						.0003
Mn	...Do...						
K_2CO_3		bi. *1.074* .0184		bi. *1.559* .0267			
$MgSO_4$						.020	
K_2SO_4	*.145* .00244	Tr.	*.083* .00145	Tr.			Tr.
SiO_2	*.583* .0100	*.117* .0020	*.350* .006	*.117* .0020	*.70* .01	.017	.014
NaCl	*.119* .00205	*.096* .001645	*.095* .00163	*.119* .0020	*.49* .007	.007	.014
$NaCO_3$	bi. *.676* .01168	bi. *1.364* .0234	bi. *1.021* .0176	bi. *.835* .0188			bi. .033
Na_2SO_4			*.110* .00199				
Organic					*2.10* .03		
Total	*14.592* .2502	*12.676* .2004	*16.649* .2854	*18.035* .3096	*18.55* .265	.378	.378
CO_2 (*a*)	36.38	35.46	37.21	38.96		.027	

Constituent.	66. Ann Arbor (S. Mann).	67. Wayland (spring).	68. Otsego.	69. Albion (Warner's spring).	70. Ypsilanti (waterworks).	71. Ypsilanti (well).	72. Hubbardston (magnetic spring).
Al_2O_3				0.004		Tr.	
$CaCO_3$	0.228	*7.50* .107	bi. 0.244	bi. .290	0.289	*9.109* .156	bi. 0.400
$CaSO_4$		*3.20* .046	.011	.058	.039	*12.948* .223	
Fe_2O_3		0	.036		.021	Tr.	.005
$FeCO_3$	.00468			bi. .029			
LiCl					Tr.		
$MgCO_3$	.08936	*.520* .074	bi. .026	bi. .080	.100	*6.370* .109	bi. .187
K_2SO_4	.00531		.020	.006			

a + Al_2O_3.

Constituent.	66. Ann Arbor (S. Mann).	67. Wayland (spring).	68. Otsego.	69. Albion (Warner's spring).	70. Ypsilanti (waterworks).	71. Ypsilanti (well).	72. Hubbardston (magnetic spring).
SiO_2			0.048	0.003	0.014	*1.159* .018	0.004
H_2SiO_3	0.012						
NaCl	.00488	*0.65* .009	.028	.021	.035	*3.600* .062	
Na_2CO_3	.00042	*1.50* .021				*1.056* .017	
Na_2SO_4	.00971			.036			
NaI	Tr.						
Nitrates					Tr.		
Volatile at red heat	.025	*8.00* .114		Loss. .017	.071	*.818* .014	
Total	.37936	*27.000* .386	.449	.546	.570	*35.04* .599	.596
Ammonia free					.00003		
CO_2	.285		8 cu. in.				
Ammonia albuminoid					.00002		

Constituent.	73. Mount Pleasant (waterworks).	74. Mount Pleasant (waterworks).	75. Midland (Reardon).	76. Detroit (Amos T. Hall).	77. Midland (magnetic spring).	78. St. Louis.
$Al_2O_3P_2O_5$					0.025	
$CaSiO_3$						0.096
$CaCO_3$	(?)	0.173	bi. 0.038	0.3919		bi. .991
$CaCl_2$					.089	
$CaSo_4$	0.620	1.044	.0443	.2826	.064	.950
$FeCO_3$				.0102		bi. .017
$MgCO_3$	.120	.067				bi. .250
MgCl				.3476	.031	
$MgSO_4$			.0560			
KCl				.1100		
K_2SO_4				.1045	1.174	
H_2SiO_3			.054			
SiO_2				.0237	.042	.041
NaCl		.086	1.155	.7252	.467	Tr.
$NaCO_3$						bi. 1.520
$NaSO_4$	.018				.315	
Loss at red heat	.100	.024			.046	.029
Organic					.035	
Total	1.130	1.580	1.416	1.9957	2.288	3.895
Nitrites	Strong.	Distinct.				
Nitrates		Strong.				
Temporary hardness	8.°					
Permanent hardness	30.°					
CO_2						.089
Ammonia free	.00008	.003				
Ammonia albuminoid	.00002	.00015				
H_2S						Tr.

	79. Mount Pleasant (test well).	80. Mount Pleasant (test well).		79. Mount Pleasant (test well).	80. Mount Pleasant (test well).
Result of inoculation	—	—	Chlorine as NaCl	.1815	.198
Number of bacteria in 72 hours	425	120	Organic residue	.470	.440
Nitrites	Large.	Very slight trace.	Inorganic residue	1.676	1.852
Nitrates	Tr.	Tr.	Total residue	2.146	2.292
Albuminoid ammonia	0.0000213	0.000072	Hardness	2.4°(?)	2.6°(?)
Free ammonia	.00012	.000043	Sulphates	Large.	Large.
Permanganate reduced	0.002	0.002			

No. 52 is of water from the Ponce de Leon spring, Grand Rapids, John DeBoe, analyst; bottled and used commercially since 1848; has no color, taste, odor, or sediment; specific weight at 59° F., 1.00465; found under 22 feet of clay; contains no nitrites; 0.000422 (0.0246) nitrates; 0.000015 (0.00087) free ammonia; and 0.000022 (0.00128) albuminoid ammonia. (For further notes and record of temperatures for different months in the year, see a later paper.)

No. 53, F. S. Kedzie, analyst for E. Shay & Son; water from 320-foot well at Harbor Springs. (See description in a later paper.)

No. 54 is of water from Greenville, February, 1888; furnished by city clerk. Oxygen reduced by permanganate 0.0003.

No. 55, Ann Arbor, water from well on north side of campus, 70 feet 8 inches deep; T. C. McNeill, analyst; temperature 50°; biennial report of State geologist (Michigan), 1861, page 203.

No. 56, F. S. Kedzie, analyst; nitrates, a slight trace; nitrites, none; water colorless, odorless, tasteless, of excellent quality; compare with analysis No. 3. This analysis is cited in Rafter's report to the city council of Traverse City as from Park Place Hotel. A full description of the numerous deep-flowing wells of Traverse City, of which this is an example, will be found in a later paper.

No. 57, Dearborn Drug and Chemical Works, analysts; primarily a boiler-water analysis; Na and K, Fe_2 and Al_2 included together. Well deepened since analysis was made. (See description in later paper.) The city is not supplied from these wells, the water being too hard, but from the bay (Nos. 2A, 2B, 2C, and 3).

No. 58, J. E. Clark, analyst; Welcome Island lithia water, 3 miles north of Pontiac, in the center of Lake Angelus.

No. 58A, an analysis of water from the Mount Clemens Pagoda springs; analysis of a much-used similar water will be found in the Appendix; C. G. Wheeler, analyst; temperature, 52°.

Nos. 59 to 62 are of waters from four out of the thirty or more springs of H. E. Eastman, 1 and 2 miles southeast of Benton Harbor; Professor Haines, analyst. The more mineralized waters, with the greater spe-

cific weight, seem to have a higher temperature and perhaps draw from a deeper layer, as follows:

No. 59, water from King David spring, Benton Harbor; temperature, 50° F.; specific weight, 1.000.

No. 60, water from Silver Queen spring, Benton Harbor; temperature, 50° F.; specific weight, 1.000125.

No. 61, water from Saul spring, Benton Harbor; temperature, 51° F.; specific weight, 1.00025.

No. 62, water from Colonel's Own spring, Benton Harbor; temperature, 51° F.; specific weight, 1.00025.

No. 63, water from Petoskey springs, F. S. Kedzie, analyst; 12° total hardness, 2° permanent hardness. Compare the analysis of water from the deep well (No. 294) in the Dundee limestone.

No. 64, water from Alma, C. A. Davis, analyst; originally stated in grains per United States gallon for the Alma Sanitarium. (See fig. 3, and compare descriptions and tests of waters from Alma wells in a later paper.) Temperature, 48.2° F.; reaction neutral or slightly alkaline.

No. 65, water from Nochemo spring; R. Fischer and A. B. Prescott, analysts; original statement in grains per United States gallon. Water bottled and sold is from flowing driven wells in a river bottom; the yellow of a chalybeate water is very apparent about them. The region is said to be an old deer-lick. (Compare analysis No. 83.)

No. 66, water from spring on land of Solomon Mann; T. C. McNeill, analyst; temperature, 50° F.; specific gravity, 1.001. Basis of sanitarium for several years. Biennial report of the State geologist (Michigan), 1861, page 204; Winchell, Geology of Washtenaw County (History of Washtenaw County), 1881, page 14. The CO_2 is partially free and partially combined acid. The water from Mount Clemens Pagoda springs (No. 58A) is similar.

No. 67, F. S. Kedzie, analyst; Wayland spring water. There are many flowing wells in Wayland, but only one is a rock well.

No. 68, cited by A. C. Peale, Bulletin U. S. Geological Survey No. 32; R. S. Kedzie, analyst. Water contains a trace of H_2S and 8 cubic inches CO_2 per gallon, and is from a rock well; the amount of potash is abnormal and reminds one of the Midland analyses.

No. 69, Warner's spring, Albion; D. Fall, analyst; cited by Peale, Bulletin U. S. Geological Survey No. 32, from Report State Board of Health, 1875, page 89; from flowing springs south of Lake Shore and Michigan Southern Railroad.

No. 70, F. S. Kedzie, analyst; water from Ypsilanti city waterworks; quality excellent. (See fig. 2.)

No. 71, 18-foot well; Dearborn Drug and Chemical Company, analysts for the Ypsilanti Electric Company; a boiler-water analysis, originally stated in grains per United States gallon.

No. 72, P. (? S.) H. Douglass, analyst; cited by Peale, Bulletin U. S. Geological Survey No. 32.

No. 73, July, 18, 1896; No. 74, Aug. 17, 1893. Nos. 73 and 74 are of water from the Mount Pleasant waterworks' 40-foot well; F. S. Kedzie, analyst. Note the apparent leaching out of sulphates in course of time. This water is not used for boilers, but river water is used instead. (See analysis No. 49.) It leaves a red coating in a porcelain dish.

No. 75, J. E. Graves (Dow Chemical Company), analyst. Water clear, neutral, odorless; tested by A. C. Lane November 2, 1897; SO_4 moderate, Ca low, Cl low; specific gravity, 1.001; 50° F.

No. 76, water from well of Amos T. Hall, Woodward avenue, Detroit; S. H. Douglass, analyst, 1854, for board of water commissioners; cited from Winchell's biennial report of the State geologist, 1861, page 203.

No. 77, water from Midland magnetic spring; cited by Peale, op. cit. (Compare Nos. 75, 248, and 249.) The amount of potash seems incredible, and suggests an error in transcription. It agrees in indicating a sulphated water. I believe that it and No. 248 are perverted versions of No. 249.

No. 78, water from St. Louis, S. P. Duffield, analyst; cited, slightly differently, by Peale, op. cit.; temperature, 50° F. This should be compared with the analysis of a water from St. Louis (No. 113), made by Kedzie December 1, 1893.

No. 79 (361), water from Mount Pleasant test well, V. C. Vaughan, analyst; July 13, 1897. Water yellowish opalescent. Microscope showed organic matter.

No. 80 (365), water from Mount Pleasant test well, V. C. Vaughan, analyst; Aug. 17, 1897. Water yellowish opalescent. Microscope showed a considerable amount of amorphous matter. The last two analyses are from the 205-foot test well. (See later paper.)

UNCLASSIFIED ANALYSES.

Among the analyses furnished me through the kindness of Professors Kedzie and Prescott there were a large number the records of which were not so exact as to make the geological source of the waters certain. It is true that, judging from the analyses, I can in each case give the probable source of the water, yet it would obviously be reasoning in a circle to thus doubtfully assign them to geological sections and then proceed to draw, from analyses so grouped, deductions as to the character of the water from a given formation. At the same time it seemed to involve too much burden on the time and kindness of the gentlemen mentioned, as well as delay in publication, to enter upon the search and correspondence necessary to ascertain with certainty the geological conditions in all cases. In a few instances the geological conditions have been determined with certainty, but too late to be available without a complete rearrangement of all the analyses.

As most of the waters sent in, especially those sent to Professor Vaughan, have been the subject of suspicion, and as most of the water sources in the State are wells in the drift, which are more open to sus-

picion than rock wells, it is obvious that most of these analyzed waters of uncertain origin belong to the group of the preceding section, waters more or less from the drift; this is the excuse for introducing these analyses here rather than later. Whenever one of these analyses seems to indicate a water not from the Pleistocene, attention is called to the fact.

Peale, in Bulletin U. S. Geological Survey No. 32, does not give the geological source of the waters analyzed. Most of them, however, I have been able to classify by determining their geological source in such ways as the following examples will indicate: The Alpena magnetic well is certainly one of the deep borings into the so-called Dundee limestone, as the temperature (52° F.) of the water, which is 10° higher than the mean annual temperature of Alpena (42°), and its sulphureted character indicate, and I have placed it accordingly. (Analysis No. 297.) The Berrien springs are uncertain, and no analysis is given. Butterworth's magnetic spring, or Grand Rapids magnetic, as I learn from Mr. Powers,[1] is a well into the Marshall, with mineral additions from the Michigan series; or, as Mr. Powers says, his own well (the Arcade) draws from the lower 18 feet of the Marshall sandstone, which is about 100 feet thick, and has less $CaCl_2$ than Butterworth's, which draws from the upper part. The waters of the Cascade springs are not analyzed. The chalybeate springs near Ann Arbor, although no analysis of the water is given, are in all probability wells in the drift (see analyses Nos. 55 and 66, from Winchell's biennial report, 1861, page 203, and Geology of Washtenaw County, 1881), and those of Wayne County may be from the drift, and are likely to be wells just above the rock. As Peale remarks, wells are often called springs, especially when the water rises markedly when struck. The Springville well is probably from the drift, but the water is not analyzed. The Eaton Rapids springs and well are flowing wells from the Coal Measures and the Parma. (Analyses Nos. 243 to 247.) The proportions of $CaCO_3$ and potash in these analyses are characteristically large.

The Erie sulphur springs are only examples of a great number of sulphur springs in the same region, flowing wells to or into the Dundee (upper Helderberg or Corniferous) limestone, of the same class as the Wyandotte or Riverside wells (analyses Nos. 296 and 300). Flint's magnetic springs at Three Rivers; in St. Joseph County, being saline are probably in the rock, as the drift well waters in that part of the State are not usually saline; while on the other hand the Berea or other saline beds of the Coldwater shales may readily be struck. The Fruitport artesian and magnetic well shows by its record and its temperature (48° F.) that it draws water from the Marshall. The water of the Grand Haven mineral spring is similar in analysis, and also comes from the Marshall (see analyses Nos. 264 to 266). The Grand Ledge water is probably from the Coal Measures. The Hubbardston magnetic spring

[1] See also Winchell's biennial report, 1861, p. 168.

(well), if it is the one of which Mr. Lincoln has furnished a record, is in the Pleistocene, but if not, as the drift is thick over all the region and as I am informed that rock has not been struck, it is probably a drift water, although it should perhaps have been included here in the unclassified section, rather than as analysis No. 72. The Lansing magnetic (Michigan Congress) well shows by its depth that it goes through the Marshall. It is plugged part way down. The temperature (53.5° F.) being not more than 7° above the mean annual temperature of the place, indicates that the main flow is from the same horizon as the deep Agricultural College well, i. e., from the Marshall, and the analyses (Nos. 241 and 242) show, as I have likewise been informed, that the upper calcic waters are not cased out. The Leslie magnetic well is almost certainly from the Coal Measures, though we have placed the analysis near those furnished by Prof. F. S. Kedzie below (No. 228). The Midland magnetic well (analysis No. 77) has been placed for comparison beside No. 78. Its temperature indicates that its depth is no greater than that of No. 78, but the analysis needs verification, and it may be merely an erroneous form of analysis 249, which water is from the Coal Measures. We have no analysis of the water from the Arcade Building mineral well at Grand Rapids, unless some of the uncertain analyses of Vaughan or Kedzie refer to it. The Moorman well (analyses Nos. 304 and 305) is, as is obvious from the description below, from the temperature (57.5° F.) of the water, and from the section shown in fig. 2, chiefly from the Helderberg limestone. Owen's mineral well (56.6° F.) and the Ypsilanti mineral well (58.1° F.) are similar. The Mount Clemens springs are from the same horizons. The Ogemaw mineral springs are in all probability from the drift and similar to those around Rose City. The Otsego mineral springs (analysis No. 68) appear to be from the drift. The Owosso spring analysis is most likely of water from one of the wells into the upper Coal Measures. Its source is, however, so uncertain that it is given below in this section (analysis No. 227). The Riverside magnetic mineral springs (Springwell's Fort) in Detroit are from the Dundee and the upper Monroe, as the temperature (50° F.) shows, and are described in the appropriate place. The St. Clair spring belongs to the same family. (See pp. 77, 78.) The St. Louis magnetic spring analysis (No. 78) is of water from a deep drift well within the coal basin. The Springlake magnetic well analysis (No. 265) belongs with the analyses of water from the Fruitport and Grand Haven wells, as all draw from the Marshall (Nos. 264 to 266). The Shawnee mineral springs probably derive their supply from the Helderberg or the immediately overlying drift, but the waters are not analyzed. The temperature (47° to 49°) is practically the mean annual temperature of the place, which shows that the wells are not deep.

Sulphur springs are very abundant in that region and apparently derive their water from the Dundee limestones, in some cases, perhaps, from the Monroe. (Compare analyses Nos. 294 to 302.)

ANALYSES BY PROFS. R. C. AND F. S. KEDZIE.

Constituent.	81. Grand Haven (hydrant).	82. Grand Haven.	83. Reed City.	84. Coldwater.	85. Ludington.	86. Pontiac.
$CaCO_3$	*4.20* .06	*7.0* .100	*5.25* .075	*9.10* .130	*6.10* .087	*10.50* 1.50
$CaSO_4$	*.56* .008		*.14* .002	*.35* .005		*.14* .002
Fe_2O_3		0	*.07* .001	*.07* .001	*.20* .003	*.28* .004
$MgCO_3$	*.296* .042	*3.0* .042	*3.52* .050	*3.50* .050	*5.90* .074	*5.32* .076
K_2SO_4		0		*.56* .008		
SiO_2		0	*.84* .012	*.14* .002	*1.00* .014	*1.40* .02
NaCl	*.12* .002	*.87* .012	*1.38* .020	*.70* .010	*2.50* .036	*.63* .009
Volatile at red heat	*3.15* .045	*5.0* .071	*2.10* .030		*2.00* .029	0
Total	*10.99* .157	*16.6* .237	*13.30* .190	*14.42* .206	*17.00* .243	*18.27* .261
Total hardness		*6.°*			*14.°*	
Permanent hardness		3.°			7.°	
Nitrates		.000324			.0005	
Nitrites						
Free ammonia	.00007	.000105			.00007	
Albuminoid ammonia	.00010	.000008			.00001	

Constituent.	87. Soldiers' Home, Grand Rapids.	88. Grand Rapids No. 1.	89. Grand Rapids No. 2.	90. Dowagiac.	91. Niles.	92. Kalamazoo.	93. Kalamazoo No. 1.
$CaCO_3$	*3.50* .122	*3.80* .126	*3.70* .124	*10.00* .143	*3.86* .127	*10.50* .150	*12.60* .18
$CaSO_4$	*1.20* .017	*.28* .004	*.20* .004	*1.50* .021	Tr.	*1.51* .022	*1.50* .021
Fe_2O_3				*.50* .007	*.56* .008		$+SiO_2$ *3.67* .052
$MgCO_3$	*2.60* .037	*3.96* .057	*4.00* .057	*2.00* .029	*5.29* .076	*7.04* .101	*4.36* .062
K_2SO_4					*0.70* .01		
SiO_2				*1.00* .014	*.96* .014	*.61* .009	
NaCl	*.45* .006	*.50* .007	*.50* .007	*2.00* .029	*.20* .003	*.47* .007	*1.37* .020
Na_2SO_4					*1.02* .015		
Volatile at red heat	*3.00* .043	*6.46* .092	*7.00* .10	*4.20* .06	*3.50* 0.050	*2.27* .03	*2.50* .036
Total	*15.75* .225	*20.00* .286	*20.50* .293	*21.20* .303	*21.23* .303	*22.40* .320	*26.00* .371
Total hardness	*14.°*	*15.°*	*15.5°*	*12.°*			*16.°*
Permanent hardness	6.°	8.°	8.5°	2.°			5.°
Nitrates	.002				.00014		.001
Free ammonia	.00005	.00015	.00008		.0002		.00002
Albuminoid ammonia	.00008	.00025	.0001		.00003		.00002
O from permanganate							.000028

Constituent.	94. Kalamazoo No. 2.	95. Dimondale.	96. Adrian.	97. Stanton.	98. Rochester.	99. Battle Creek.	100. Owosso.
$CaCO_3$	9.80 / .140	12.95 / .185	8.75 / .125	13.25 / .189	14.50 / .207	.....	10.78 / .154
$CaSO_4$	1.60 / .023	.27 / .004	Tr.	1.54 / .022	2.00 / .029	.....	2.10 / .03
Fe_2O_3	.30 / a .004	.05 / .001	.....	.....	1.00 / .014	.....	.....
$MgCO_3$	4.66 / .067	5.25 / .075	6.62 / .095	5.81 / .083	2.25 / .032	.....	9.52 / .136
KCl	.....	.28 / .004	.....	.....	.....	.....	.....
SiO_2	.....	.20 / .003	.....	1.00 / .014	.....	.....	.07 / .001
NaCl	1.64 / .023	.70 / .01	.33 / .005	.40 / .006	.75 / .011	2.00 / .029	2.10 / .03
Volatile at red heat	3.00 / .043	2.70 / .039	7.00 / .100	2.00 / .029	3.00 / .043	16.00 / .229	1.68 / .024
Total	21.00 / .30	22.40 / .32	22.70 / .324	23.00 / .329	24.50 / .35	25.00 / .357	26.25 / .375
Total hardness	14.°	.....	15.5°	21.°	19.°	10.°	.....
Permanent hardness	6.°	.....	10.°	10.°	8.°	9.°	.....
Nitrates	.0005	.....	.....	.....	Tr.	.....	.....
Free ammonia	.00005	.00002	.00015	.....	.00005	.00003	.....
Albuminoid ammonia	.00002	.00001	.00020	0.0	.00001	.00025	.....
O from permanganate	.00025	.....	.....	.....	.....	.....	.....

Constituent.	101. Port Huron.	102. Howell.	103. Tecumseh.	104. Moline.	105. Belding.	106. Lapeer (Home of Feeble-Minded).	107. Lapeer.
$CaCO_3$	8.40 / .12	14.10 / .201	14.28 / .204	11.20 / .160	39. / .557	.....	.....
$CaSO_4$	5.35 / .077	2.00 / .029	4.50 / .064	1.35 / .019	2.80 / .04	9.90 / .141	.....
Fe_2O_3	Tr.	1.00 / .014	.10 / .001	.50 / .007	.20 / .003	.08 / .001	.....
$MgCO_3$	3.15 / .045	5.00 / .071	6.62 / .095	12.25 / .175	.50 / .007	3.42 / .049	.....
SiO_2	.....	1.40 / .20	.....	1.00 / .014	.....	.30 / .004	.....
NaCl	.53 / .008	1.00 / .014	.50 / .007	.80 / .011	5.00 / .071	5.40 / .077	b16.33 / b.233
Na_2SO_4	.....	.....	.....	.....	.....	20.10 / .287	.....
Volatile at red heat	10.5 / .15	3.60 / .051	6.00 / .086	5.8 / .083	3.50 / .05	4.20 / .60	20. / .286
Total	28.00 / .40	28.10 / .401	32.00 / .457	32.9 / .470	51. / .729	43.40 / .620	80. / 1.143
Total hardness	17.°	20.°	17.°	.....	.....	11.°	14.°
Permanent hardness	9.°	10.°	6.°	.....	.....	7.°	10.°
Nitrates	.....	.000	.....	.....	.....	Tr.	.002
Nitrites	.....	.....	.....	.....	.....	Tr.	0
Free ammonia	.00005	.00006	.....	.....	.000003	.00001	.00001
Albuminoid ammonia	.00009	.00005	.....	.....	.000001	.00003	.000004
Oxygen of permanganate reduced.	.....	.....	.....	.....	.0005	.....	.....

a + SiO_2.

b All chlorides.

Constituent.	108. Saginaw (Brand & Hardin).	109. Saginaw (Washington ave.).	110. Saginaw (Tower Block).	111. St. Charles.	112. Bay City.	113. St. Louis.	114. Saginaw (William Hicks).
$CaCO_3$	*3.00* .043	*6.40* .091	*11.55* .165	*8.40* .120	*14.70* .210		
$CaSO_4$	*5.40* .077	*9.20* .131		*9.80* .140	*31.99* .457	*39.90* .570	*28.* .400
RSO_4			*23.10* .330				
Fe_2O_3	*.35* .005	*.50* .007				*.35* .005	Tr.
$MgCO_3$	*3.92* .056	*5.50* .079		*8.50* .121	*8.47* .121	*26.81* .383	
$MgSO_4$							*15.3* .219
KCl						*13.65* .195	
SiO_2	*1.00* .014	*1.00* .014			*a .14* .002	*.28* .004	*.5* .007
NaCl	*28.83* .412	*30.28* .433	*2.00* .029	*33.90* .470	*55.20* .760	*100.31* 1.433	*113.7* 1.696
Na_2SO_4	*19.00* .271	*20.12* .287					
SO_3							*2.1* .003
Total mineral						*200.30* 2.861	
Volatile at red heat	*5.50* .079	*6.00* .086	*3.00* .043	*8.40* .120	*10.50* .150		*17.5* .25
Total	*67.0* .957	*79.* 1.129	*50.10* .716	*68.00* .971	*119.* 1.700		*210.* 3.000
Total hardness	*14.°*	*18.°*			*18.°*		*19.°*
Permanent hardness	10.°	13.°			14.°		13.°
Nitrates		.021					
Nitrites		0.0					
Free ammonia		.00050			.00013	.00003	
Albuminoid ammonia		.00025			.00003	.00002	

Constituent.	115. Flushing No. 1.	116. Flushing No. 2.	117. Flushing No. 3.	118. Flushing No. 4.	119. Frost.	120. Vassar.	121. Caro.
$CaCO_3$	*9.00* .129			*2.80* .04	*20.60* .294		*21.00* .30
$CaSO_4$					*20.00* .286	*105.7* 1.51	*185.50* 2.65
Fe_2O_3	*2.00* .029				*.25* .003	*1.0* .014	*.70* .01
$MgCO_3$	*1.13* .016	*1.00* .014	*2.00* .029	*1.00* .14	*13.30* .19	*17.5* .25	*19.60* .28
KCl							*3.50* .05
K_2SO_4						*10.5* .15	

a + Fe_2O_3.

Constituent.	115. Flushing No. 1.	116. Flushing No. 2.	117. Flushing No. 3.	118. Flushing No. 4.	119. Frost.	120. Vassar.	121. Caro.
SiO_2	5.00 .071				1.15 .016	1.5 .021	
NaCl	158.69 2.267	141.27 2.018	Not determined.	122. 1.743	168.70 2.41	277.2 3.96	466.90 6.67
Na_2CO_3	17.08 .244	22.00 .314	43.50 .671	41.00 .586			
Na_2SO_4	89.00 1.271	3.50 .05	7.80 .111	5.40 .077			
Total mineral	289.90 4.156						
Volatile at red heat		4.90 .07	9.80 .140	7.00 .10	14. .2		
Total		181.10 2.573	233.80 3.340	179.20 2.56	238. 3.400	413.4 5.906	697.20 9.96
Total hardness		2.°	4.°				
Permanent hardness		1.°	1.5°				
Free ammonia		.00012	.00015		.00015		
Albuminoid ammonia		.00002	.00002		.00005		

Constituent.	122. Wales.	Constituent.	122. Wales.
$CaCl_2$	59.64 .852	KCl	5.00 .071
$CaSO_4$	1.00 .014	NaCl	1158.88 16.47
Fe_2O_3	.74 .011	Total mineral residue	1355.8 17.94
MgCl	36.54 .522		

Of the foregoing analyses No. 110, and doubtless others, should be credited to Prof. R. C. Kedzie alone. It should not be forgotten that these are not all the analyses furnished me by the Professors Kedzie, but only those which I preferred not to class geologically.

The first analysis of this list, being doubtless of water from the Grand Haven waterworks, which obtain their supply from driven wells, might perhaps have been included among those in the Pleistocene if the very low percentage of mineral matter did not suggest that the source is practically Lake Michigan, filtered through sand. The analysis is suggestively similar to that of Muskegon Lake (No. 2).

There is next a series of analyses, Nos. 82 to 105, in every respect comparable to the series Nos. 55 to 89. As arranged, the solids increase from one-fifth to one-half of an ounce per cubic foot of water, which is the normal range. The carbonates invariably form by far the largest proportion of the solid matter. The amount of gypsum is usually barely a tenth as great, and there is a small but variable amount of salt, which does not increase regularly with the amount of mineral matter, and when high may be assigned in part to sewage con-

tamination. The wells furnishing these waters occur all over the State except in the central region around Midland. It is noteworthy that the percentage of solids is most commonly near 0.30 per thousand, and the hardness correspondingly near 15°. There is no reason why any of these analyses may not be of waters from common wells in surficial deposits, and most of them are undoubtedly such. No. 83, from Reed City, is of water from a region where I could find no wells which had reached bed rock, even when 100 feet deep. The same statement holds true at Ludington. On the other hand, in cases like Owosso the well may pierce bed rock a little, though near Owosso plenty of water and even flows are found in the drift. Taken as a whole, the analyses belong to a fairly well-defined type of water from the drift.

With only two transitional analyses, those at Lapeer (Nos. 106 and 107), we pass, with an increasing proportion of solid matter, to an entirely different type of analysis. The total solids quickly double in amount, reaching about an ounce per cubic foot. But the lime and magnesia, or at any rate the carbonates, fall off, and instead there are sulphates and salt. Frequently there is more chlorine and sulphuric acid than can be satisfied by their usual bases, sodium and calcium, and we have sodic sulphate, potassic chloride, and other salts.

All the places from which analyses of this type come are well within the basin of the Marshall sandstone, except Wales and Vassar, and may be supposed to derive their percentage of sulphates from the gypsum of the Michigan series and the decomposing sulphide of iron that occurs with the coal.

Some of these analyses—e. g., those from Saginaw (Nos. 108 to 110), from St. Charles (No. 111), from Bay City (No. 112), and from St. Louis (No. 113, compare No. 78)—show a considerable amount of lime and no more mineral matter than often occurs in waters from drift wells of this region, and may either be from such wells or from wells that go a short distance into the rock. On the other hand, wells like the Flushing wells, with water containing so low a percentage of lime, yield waters so extremely soft that one can hardly believe them to be derived from the drift, when he considers how much limestone and gypsum are disseminated through them. From the evidence of the analyses alone, therefore, one could say that the water must come from some of the Coal-Measure sandstones below the drift, like the water of the Bancroft House, Saginaw (the prominent hotels in Saginaw have their own artesian wells down into the sandstone), tests of which indicate water of this character with Na_2SO_4. The Saginaw analyses are intermediate in character, as would be natural in waters from wells just from the base of the drift, but the generally sulphated type is confirmed by the analyses of Heim Brothers. The water of analysis No. 108 is reported by Kedzie as "colorless, odorless, nearly tasteless, and good for domestic use." The water of No. 109 is only "fair, having too much sulphates." Both blacken very slightly on ignition. The water of No.

110 is "clear, bright, tasteless, and odorless; would be excellent but for the large amount of sulphates." The Brand & Hardin well (analysis No. 108) gave Heim Brothers 0.879 solids (61.5 grains per gallon), and the Washington avenue well (analysis No. 109) 1.043 solids (73 grains per gallon). Our inference that the waters of the Flushing analyses come from wells in the Coal Measures is confirmed by the fact that there are many such rock-drilled wells there. The well of W. Wartzel (analysis No. 119) was said to have been bored in 1896 to a depth of only 40 feet. The water flows naturally, with several feet head; temperature about 45°; specific weight in 1899, 1.007. Analyzed March 5, 1896. The last three analyses show more mineral matter than the water from any drift well known. The Vassar and Caro wells would naturally tap the gypsiferous Michigan series, and the Wales well the Berea grit. In confirmation of this supposition the Vassar and Caro analyses are strong in sulphates, while the Wales analysis is strong in salt and the earthy chlorides and low in sulphates—a thoroughly characteristic Berea grit analysis. Accordingly, analyses Nos. 82 to 104 are most probably of water from wells in the drift; analyses Nos. 108 to 121 of water from the Carboniferous above the Marshall, while No. 122, from Wales, is of water from the Berea, and may be compared with analyses at Birmingham (No. 285) and Utica (No. 225), towns which are similarly situated.

SANITARY ANALYSES BY PROF. V. C. VAUGHAN.

In the large and interesting list of sanitary analyses which have been furnished by Prof. V. C. Vaughan some are not complete, and frequently the total solids are not given. It seemed impracticable, therefore, to arrange them in the usual way, and hence they have been given a special tabulation of their own. The gaps in his numbering (given in parentheses) are in general due to the omission of analyses from other States or from the northern peninsula of Michigan.

There is a general parallelism between this series of analyses and those of Professor Kedzie, and many cross references have been inserted. It will be found that many of the analyses showing especially small amounts of solids belong in one of three classes. (1) Like the Petoskey (analyses Nos. 130 to 132), they are probably surface waters, or from lakes; or (2) there is good independent evidence that they are strictly surficial, largely from rain-water wells; or (3) they come from the sands of the modified drift or glacial drainage, like that at Lowell (analyses Nos. 123 and 124). It is noteworthy that inoculation is nearly as likely to produce bad results in these as in more highly mineralized waters. In other words, exceptionally low mineralization often means dilution with rain water, and that implies exposure to surface contamination. As in the Kedzie analyses, the vast bulk of these samples contain from one-fifth to one-half of an ounce of solid matter per cubic foot. The analyses are rather widely distributed, though of course the more populated

part of the Lower Peninsula has the greater number. Most of these analyses are doubtless of water from wells in the drift (i. e., Pleistocene), although some, e. g., Eastlake and Manistee (analyses Nos. 146 and 153), may be of water from the lakes, and others, like some of the Lansing analyses, may be of waters from rock wells and belong to the following section.

There is a somewhat larger number of transition analyses than in the case of the Kedzie analyses, having from 0.500 to 0.650 parts per thousand (ounces per cubic foot) of solids. Some of these evidently belong to the previous group, however, and merely have more organic matter than usual. (See analyses Nos. 205 to 211.) Other analyses are of waters from wells which in all probability draw their supplies from bed rock, e. g., the Saginaw well (analysis No. 214), with its comparatively soft water, is probably of the sodic-sulphate type. It is worth noting that all such wells, except No. 209 at Kalamazoo, are within the area covered by rocks above the Marshall, and should probably be included among the analyses of the next section. The remaining analyses, with the exception of one or two (No. 217—water presumably contaminated with the waste bittern of salt manufacture—and No. 218), are most probably of waters from rock, and usually there is corroboratory evidence which renders it possible to fix also the stratum from which the water comes.

The Holt well (analysis No. 221) probably draws water from the Grand Rapids limestone or from a horizon near.

The Holland (analysis No. 219), low in sulphates and strong in chlorides, is an analysis characteristic of water from the Marshall. A similar analysis of water within the coal basin would suggest strong contamination. The Wyandotte water (analysis No. 220) would seem to be from the Dundee limestones. The Adrian waters (analyses No. 222, etc.) are peculiar. It may be that they are contaminated with sulphate of iron from the sulphides in the Ohio black shale.

The two Imlay City wells (analyses Nos. 223 and 224) almost certainly draw water from the Coldwater shales or the lower Marshall. Under Imlay City water from the Berea would be much salter, as the Wales and other analyses show, and that from the Napoleon sandstone would contain less salt.

The Utica well (analysis No. 225) is shown to be in the Berea, by the same line of argument which applies to the Wales well (analysis No. 122), which is similarly situated and connects the Utica well with the Birmingham wells. The latter are certainly in the Berea.

No. 299, water from Alpena, is classed solely on the basis of its analysis, which resembles the tests of waters from the rock wells of Alpena in the Traverse or deeper limestones.

The analyses of waters from around Bay City are very puzzling, owing to the leakage from deep salt wells, and Prescott's paper tends to warn against rashness in diagnoses.

In the analyses reported by Vaughan the number, according to Vaughan's list, follows in parentheses after the serial number (the numbers omitted representing analyses outside our purview). Next follows the identification—the name of the place, the date of the analysis, and, when stated, the origin of the water. The water is understood to be colorless, odorless, and neutral, if nothing to the contrary is stated. The hardness is given on the usual (Clark's) scale—i. e., the number of grains of $CaCO_3$ per gallon which would be required to make a water equally hard. The total residue (obtained by evaporation at 110° C.) and total inorganic residue are self-explanatory. As remarked, the specific gravity of the water is neglected, which makes a perceptible error only in the analyses from No. 217 on. The quantities are in parts per thousand. The row of figures after "organic" (i. e., loss on ignition) obviously represents the differences between the two residues. The chlorine is computed as salt (NaCl). The next row of figures above gives the parts of potassium permanganate reduced by organic matter, and, in the rows above, the free and albuminoid ammonia, and the nitrates (N_2O_5) and nitrites (N_2O_3) in parts per thousand. The sulphates when given are computed as SO_3. It will be noticed that the ammonia is quite prominent even in the waters from such wells as the Mount Pleasant of the previous section, which is deep and free from possible surface contamination (analyses Nos. 79 and 80). The first two rows of figures give the biological examination, viz, the result of inoculation of cultures on the health of animals (no effect on the health being indicated by a —) and the number of bacteria per cubic centimeter after standing 72 hours.

Professor Vaughan gives the following explanatory notes:

While no absolute standard for the chemical purity of drinking water can be given, the following conclusions may be regarded as approximately correct:

(1) The total residue should not exceed 500 parts per million.

(2) The inorganic residue may constitute the total residue.

(3) The smaller the amount of organic residue the better the water.

(4) The amount of earthy bases should not exceed 200 parts per million.

(5) The amount of sodium chloride should not exceed 10 parts per million. A larger amount may be expected, however, in certain salt-producing districts.

(6) The amount of sulphates should not exceed 100 parts per million.

(7) The organic matter in 1,000,000 parts of the water should not reduce more than 8 parts of potassium permanganate.

(8) The amount of free ammonia should not exceed 0.05 parts per million.

(9) The amount of albuminoid ammonia should not exceed 0.15 parts per million.

(10) The amount of nitric acid should not exceed 0.5 parts per million.

(11) The best waters contain no nitrous acid, and any water which contains it in quantity sufficient to be estimated should not be regarded as a safe drinking water.

The word trace ("tr.") whenever used indicates the existence of the substance in quantity sufficient to be recognized by the test, but too small to be determined quantitatively.

Explanation of microscopical examination, i. e., description of deposit, if any, magnified 100 diameters and 500 diameters:

Six ounces of water are placed in a conical glass, and the deposit, if any, is examined after from 12 to 24 hours. The presence of any appreciable deposit, especially

if it be of animal or vegetable nature, would detract from the suitability of the water.

The bacteriological examination consists in counting the number of germs developed on a gelatine plate inoculated with one drop of water:

(1) After 24 hours, (2) after 48 hours, (3) after 72 hours. Then follow remarks on the kinds of germs observed.

Inoculation experiments are conducted as follows:

The animals inoculated with germs are white rats, guinea pigs, or rabbits; the method of inoculation, into abdominal cavity. The kind, amount, and age of culture used is noted, the effect on the animal's health, and eventually its post-mortem appearance. One drop of the water is added to 1 dram of some culture medium, such as beef tea, and this, after it has been kept at the temperature of the body for 24 hours or longer, is used for inoculating the animals.

	123 (190). Lowell, T. 6 N., R. 9 W.	124 (192). Lowell, T. 6 N., R. 9 W.	125 (169). Pontiac.	126 (168). Sand Beach.	127 (369). Lansing.	128 (257). Port Huron.	129 (320). Pontiac.
Result of inoculation.	—	+	—	—.	—	—	+
Number of bacteria in 72 hours	25	Liquefied.	4874	812	230	Liquefaction.	400
Nitrites		Tr.					Tr.
Nitrates		Tr.				Tr.	Tr.
Albuminoid ammonia	0.0004	0.0005	0.00006	0.00008	0.000021	0.000126	0.000174
Free ammonia	Tr.	Tr.	.00002	.00002	.000013	.000006	.000044
K Permanganate reduced	.0015	.002	.002	.003	.002		
Chlorine as NaCl	.0003	.0005	.002	.002	.00825	.00825	.00148
Organic residue	.005	.007	.011	.020	.017	.030	.012
Inorganic residue	.023	.023	.024	.035	.041	.040	.0584
Total residue	.028	.030	.035	.055	.058	.070	.0704
Hardness	8.°	8.°	2.5°	5.5°	4.°	2.°	6.°
Sulphates				Tr.		Ft. tr.	

No. 123 (190). Lowell, T. 6 N., R. 9 W. July 17, 1893. Microscope shows molds. The hardness assigned to this and the following analysis is not consistent with the low amount of total solids.

No. 124 (192). Lowell, T. 6 N., R. 9 W. July 7, 1893. Microscope shows a few vegetable fibers.

No. 125 (169). Pontiac. December 16, 1892. Microscope shows indeterminate granules. This is so much softer than any of the other Pontiac analyses (Nos. 129, 183, 139, 150, 175, 190–192, 211, and 218) that, as is in the previous analysis, rain-water contamination is indicated.

No. 126 (168). Sand Beach. December 6, 1892. From a well which must be shallow, as deeper wells soon pass into the Coldwater series and are saline. Microscope shows indeterminate granules.

No. 127 (369). Lansing. September 6, 1897. From the waterworks, which draw their supply chiefly from wells in gravel beneath clay; but deep rock wells have also been bored. Very small amount of organic matter.

No. 128 (257). Port Huron. March 9, 1895. Microscope shows wood fiber, algæ, unicellular plants and animals, vegetable débris, inorganic deposits. Color, milky; odor, musty; reaction, alkaline.

No. 129 (320). Pontiac. July 10, 1896. From a well which is almost certainly a shallow one in the drift. Microscope shows a small amount of vegetable and inorganic débris.

	130 (205). Petoskey.	131 (206). Petoskey.	132 (207). Petoskey.	133 (95). Pontiac.	134 (245). Grand Rapids.	135 (157). Bay City.	136 (136). Ithaca.
Result of inoculation.	—	—	—	—	—	.....	—
Number of bacteria in 72 hours	0	0	0	190	2,600	570	0
Nitrites	.....	.....	Tr.	.....	.....	Tr.	.....
Nitrates	.....	.....	.....	Very slight tr.	Strong tr.	Tr.	.....
Albuminoid ammonia	0.000008	0.000006	0.000006	0.000574	0.000113	0.000125	0.00024
Free ammonia	.000002	.000002	.000002	.000422	.000014	.000344	.000302
Permanganate reduced.....	.....	.....	.....	.02212	.....	.0158	.05114
Chlorine as NaCl	.00082	.00082	.00082	.0099	.0165	.0145	.028
Organic residue.....	.040	.050	.040	.054	.040	.015	.060
Inorganic residue....	.050	.050	.070	.070	.100	.133	.089
Total residue	.090	.100	.110	.124	.140	.148	149
Hardness	7.°	7.°	7.°	12.°	4.5°	11.3°	10.2°
Sulphates.....	.....	.....	.....	.....	Tr.	Strong tr.	Tr.

No. 130 (205). Petoskey. February 9, 1894. Microscope showed small amount of algæ and plant detritus, reaction alkaline.

No. 131 (206). Petoskey. February 9, 1894. Microscope showed small deposit of unicellular plants and plant detritus, reaction alkaline.

No. 132 (207). Petoskey. February 9, 1894. Microscope showed inorganic matter, algæ, and plant detritus, reaction alkaline.

No. 133 (95). Pontiac. August 21, 1890. Town water supply; slightly turbid. Microscope (100 diameters) showed organic material, yellow, red, and black, animalculæ; (500 diameters) several species of diatoms, green algæ, blue algæ, amœbæ, violet spores, yellow reticulated organic material, fibers, Entomostraceæ.

No. 134 (245). Grand Rapids. December 20, 1894. Slightly milky, alkaline. Microscope showed inorganic matter, vegetable débris, a few unicellular plants.

No. 135 (157). Bay City. October 1, 1892. Microscope showed carbonate of lime, pigment granules, bits of woody fiber, floculent matter. It is a well, and judging by analysis is shallow.

No. 136 (136). Ithaca. February 12, 1892. Microscope showed crystals of calcium carbonate; cloudy.

	137 (305). East Tawas.	138 (79). Eastlake.	139 (97). Pontiac water supply.	140 (133). Hastings.	141 (178). Northville.	142 (239). Petoskey.	143 (132). Ithaca.
Result of inoculation.	—	—	—	—	+	—	+
Number of bacteria in 72 hours	27	.....	18	850	4,300	400	500
Nitrites	Tr.	.....	Very slight tr.	Tr.	Tr.	Tr.	.....
Nitrates	Tr.	0.000202	Very slight tr.	Tr.	Tr.	.....	.....
Albuminoid ammonia	0.000062	.000058	0.00035	0.00011	0.00005	0.00012	0.00016
Free ammonia	.0000053	.000067	.00013	.0002	.00001	.00002	.00041
Permanganate reduced.....	.....	.0004662	.02307	.1311	.0075	.....	.04318
Chlorine as NaCl	.0099	.04474	.0099	.018	.0035	.00165	.025
Organic residue.....	.090	.0630	.064	.065	.047	.040	.072
Inorganic residue....	.060	.101	.101	.105	.140	.150	.118
Total residue	.150	.164	.165	.170	.187	.190	.190
Hardness.....	7.9°	4.70°	11.5°	11.6°	15.°	9.°	9.5°
Sulphates.....	.....	.0485	.....	Tr.	Tr.	.....	Tr.

No. 137 (305). East Tawas. March 7, 1896. Alkaline. Microscope shows inorganic matter and vegetable débris.

No. 138 (79). Eastlake. May 13, 1890. From a well. Microscope (100 diameters) shows slight traces of fresh-water algæ; (500 diameters) a few threadlike Vibrios.

No. 139 (97). Pontiac. August 21, 1890. Town water supply. Microscope (100 diameters) shows yellow organic material, fibers; (500 diameters) many short, rod-shaped germs, several species of diatoms, fibers, Palmellaceæ, Entomostraceæ.

No. 140 (133). Hastings. February 3, 1892. From a well and smells musty. Microscope shows vegetable fibers, molds, Paramecia.

No. 141 (178). Northville. September 30, 1893. From a well. Microscope shows some vegetable débris.

No. 142 (239). Petoskey. September 20, 1894. Alkaline. Microscope shows algæ, infusoria, bacteria, plant detritus, inorganic matter.

No. 143 (132). Ithaca. February 3, 1892. Microscope shows dust and dirt, cloudy in color, with a slight odor.

	144 (363). Battle Creek.	145 (246). Grand Rapids.	146 (364). Eastlake.	147 (138). Holland.	148 (341). Traverse City.	149 (256). Port Huron.	150 (96). Pontiac.
Result of inoculation.	—	—	—	—	—	+	—
Number of bacteria in 72 hours	14,020	1,300	263	340	Liquefied.	Liquefaction.	48
Nitrites	Tr.		Tr.	Tr.			.0109
Nitrates		Tr.	0.00005	Tr.	Tr.	Tr.	Very slight tr.
Albuminoid ammonia	0.0000293	0.000136	.00014	0.000166	0.0000346	0.000132	0.000302
Free ammonia	.000005	.000009	.000065	.000514	.0000026	.000007	.000266
Permanganate reduced	.002		.002	.02212	.002		.018644
Chlorine as NaCl	.0132	.0099	.002	.015675	.00625	.0099	.009075
Organic residue	.062	.09	.091	.090	.096	.07	.124
Inorganic residue	.137	.110	.111	.120	.123	.150	.096
Total residue	.199	.20	.202	.210	.219	.220	.220
Hardness	7.6°	8.°	11.°	9.°	13.2°	2.1°	11.5°
Sulphates		0		Tr.		Tr.	

No. 144 (363). Battle Creek. August 10, 1897. Microscope shows small amount of organic débris.

No. 145 (246). Grand Rapids. December 20, 1894. Colorless and odorless; alkaline. Microscope shows small deposit of no significance. This is one of a long series. (See index.)

No. 146 (364). Eastlake. August 11, 1897. Microscope shows a small amount of amorphous matter.

No. 147 (138). Holland. March 2, 1892. From a deep well. Cloudy. Microscope (100 diameters) shows indeterminate granules; (500 diameters) vegetable detritus. This is probably from the Marshall sandstone, as rock is not far from surface at Holland, but the expression "deep" may mean only beneath the clay.

No. 148 (341). Traverse City. November 4, 1896, at the same time as No. 163. Microscope shows very small amount of vegetable débris. (See index for other analyses.)

No. 149 (256). Port Huron. March 29, 1895. Milky, musty, alkaline. Microscope shows algæ, wood fiber, inorganic deposits, much vegetable débris, unicellular plants and animals.

No. 150 (96). Pontiac. August 2, 1890. Town water supply. Microscope (100 diameters) shows yellow organic material, colorless fibers; (500 diameters) many short, rod-shaped germs, several species of diatoms, yellow algæ, orange algæ, Cymbella ehrenbergii, fibers, Entomostraceæ.

	151 (167). Eastlake.	152 (279). Caro.	153 (270). Manistee.	154 (241). Grand Rapids.	155 (176). Kalamazoo.	156 (237). Grand Rapids.	157 (235). Grand Rapids.
Result of inoculation.	+	—	—	—	—	—	+
Number of bacteria in 72 hours	180	25	Liquefaction.	2,500	350	160	200
Nitrites	Tr.	Tr.		Tr.	0.0003	Tr.	Tr.
Nitrates	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
Albuminoid ammonia	0.00071	0.00002	0.000075	0.00004	.00012	0.00008	0.000056
Free ammonia	.0003	.00019	.000003	Tr.	.00004	.000006	.000003
Permanganate reduced	.10902	.005			.0012		
Chlorine as NaCl	.01419	.006	.00165	.0165	.00247	.00713	.00713
Organic residue	.110	.029	.050	.090	.090	.070	.080
Inorganic residue	.114	.201	.180	.140	.160	.180	.170
Total residue	.224	.230	.230	.230	.250	.250	.250
Hardness	16.5°	5.6°	8.5°	9.°	10.°	8.°	8.°
Sulphates		Tr.	Tr.	Tr.	Tr.		

No. 151 (167). Eastlake. November 21, 1892. From town supply pipes. Clear after filtering; putrid odor on standing. Microscope shows vegetable débris. (Compare with No. 138; the deep-rock well character of this water is plain.)

No. 152 (279) Caro. July 27, 1895. Microscope shown vegetable débris. Cloudy, alkaline.

No. 153 (270). Manistee. June 29, 1895. Probably from lake. Slight milkiness, alkaline. Microscope shows vegetable débris and inorganic matter, algæ, infusoria. Agrees quite closely with Nos. 1 and 146.

No. 154 (241). Grand Rapids. November 5, 1894. Alkaline. Microscope shows algæ, desmids, diatoms, bacteria, infusoria, vegetable débris, inorganic matter.

No. 155 (176). Kalamazoo. October 31, 1893. Odor stale; alkaline. Microscope shows vegetable débris, with vegetable and animal microorganisms.

No. 156 (237). Grand Rapids. September 4, 1894. Alkaline. Microscope shows algæ, infusoria, inorganic matter, vegetable débris.

No. 157 (235). Grand Rapids. September 4, 1894. Alkaline. Microscope shows inorganic matter, vegetable débris, infusoria, algæ.

	158 (227). Grand Rapids.	159 (189). Holland.	160 (224). Grand Rapids.	161 (271). Manistee.	162 (226). Grand Rapids.	163 (342). Traverse City.	164 (367). Traverse City.
Result of inoculation.	+	—	+	—	+	+	—
Number of bacteria in 72 hours	Liquefaction.	120	Liquefaction.	Liquefaction.	Liquefaction.	Liquefied.	12
Nitrites		Tr.					
Nitrates	Tr.	Tr.		Tr.		Tr.	
Albuminoid ammonia	0.00003	0.000134	0.0002	0.000082	0.000215	0.0000846	0.00006
Free ammonia	.000016	.000088	.00008	.000006	.000055	.0000026	.000005
Permanganate reduced		.00948				.002	.002
Chlorine as NaCl	.0165	.00693	.01485	.00247	.01485	.00825	.0033
Organic residue	.090	.070	.057	.07	.167	.120	.100
Inorganic residue	.160	.180	.202	.190	.113	.160	.185
Total residue	.250	.250	.259	.260	.280	.280	.285
Hardness	11.°	10.°	12.°	9.1°	12.°	13.2°	11.°
Sulphates		Tr.		Tr.			Slight tr.

No. 158 (227). Grand Rapids. August 9, 1894. Alkaline. Microscope shows vegetable débris, diatoms, infusoria, bacteria.

No. 159 (139). Holland. March 3, 1892. From shallow well. Microscope (100 diameters) shows indeterminate granules; (500 diameters) vegetable cells, a few green algæ. (Compare with No. 147 and note that the water from the shallow well is more highly mineralized.)

No. 160 (224). Grand Rapids. August 3, 1894. Alkaline. Microscope shows vegetable débris, algæ, diatoms, infusoria. (See index for other analyses.)

No. 161 (271). Manistee. June 29, 1895. Alkaline. Microscope shows a few unicellular plants and animals.

No. 162 (225). Grand Rapids. August 3, 1894. Alkaline. Microscope shows vegetable débris, algæ, diatoms, infusoria.

No. 163 (342). Traverse City. November 9, 1896. Microscope shows small amount of vegetable débris. (See No. 148.)

No. 164 (367). Traverse City. August 27, 1897. From lake or well. Slight opalescence. Microscope shows small amount of vegetable débris.

	165 (226). Grand Rapids.	166 (268). Grand Rapids.	167 (242). Grand Rapids.	168 (292). Dowagiac.	169 (329). Grand Rapids.	170 (78). Three Rivers.	171 (104). Three Rivers.
Result of inoculation	+	—	—	+	—	—	—
Number of bacteria in 72 hours	Liquefaction.	50	2,000	50	40	8	248
Nitrites			Tr.			0.000043	Very ft. tr.
Nitrates	Tr.	Very ft. tr.	Tr.	Tr?			
Albuminoid ammonia	0.000052	0.000208	0.000043	0.000013	0.0000133	.000019	0.000212
Free ammonia	.000026	.0000132	Tr.	.000015	.0001286	.000015	.000198
Permanganate reduced					.001	.0005	.005372
Chlorine as NaCl	.01465	.0198	.0165	.00181	.002475	.006288	.0099
Organic residue	.110	.070	.0750	.050	.160	.130	.0760
Inorganic residue	.190	.220	.215	.240	.132	.163	.220
Total residue	.300	.290	.290	.290	.292	.293	.296
Hardness	11.°	8.3°	9.°	13.°	17.°	14.2°	14.°
Sulphates		Ft. tr.	Tr.	Tr.			

No. 165 (226). Grand Rapids. August 9, 1894. Alkaline. Microscope shows vegetable débris, algæ, diatoms, bacteria, infusoria.

No. 166 (268). Grand Rapids. June 19, 1895. Yellowish, alkaline. Microscope shows algæ, diatoms, inorganic deposits, unicellular plants and animals.

No. 167 (242). Grand Rapids. November 5, 1894. Alkaline. Microscope shows algæ, desmids, diatoms, bacteria, infusoria, vegetable débris, inorganic matter.

No. 168 (292). Dowagiac. November 19, 1895. Alkaline. Microscope shows inorganic matter.

No. 169 (329). Grand Rapids. August 22, 1896. From Grand River; filtered. Opalescent. Microscope shows small amount of amorphous sediment.

No. 170 (78). Three Rivers. May 5, 1890. From a well. Microscope (100 diameters) shows inorganic salts; (500 diameters) hexagonal crystals, a few algæ, yellowish amorphous organic matter in small amount.

No. 171 (104). Three Rivers. December 23, 1890. Microscope shows algæ, crystals, amorphous material, diatoms, Draparnaldia, crystals of NaCl, yellowish amorphous matter.

	172 (376). Lansing.	173 (276). Flint.	174 (265). Grand Rapids.	175 (291). Pontiac.	176 (269). Grand Rapids.	177 (127). Adrian.	178 (248). Grand Rapids.
Result of inoculation.	—	+	+	—	—	+	—
Number of bacteria in 72 hours	97	Liquefied.	Liquefaction.	31	75	44	50
Nitrites		Tr.				Tr.	
Nitrates		Tr.		Tr.		Tr.	Tr.
Albuminoid ammonia	0.0000133	0.00004	0.000047	0.0001	0.000044	0.0002	0.00008
Free ammonia	.0000053	.00001	.000016	.00009	.00002	.00008	.00001
Permanganate reduced	.002	.006				.008	
Chlorine as NaCl	.0033	.005	.01897	.0066	.007425	.010	.0132
Organic residue	.110	.020	.030	.060	.07	.0474	.120
Inorganic residue	.189	.280	.270	.240	.230	.257	.190
Total residue	.299	.300	.300	.300	.300	.3044	.310
Hardness	9.8°	10.°	7.7°	12.°	7.5°	12.1°	10.°
Sulphates			Ft. tr.	Ft. tr.	Ft. tr.	Tr.	Ft. tr.

No. 172 (376). Lansing. November 19, 1897. From wells in drift. Microscope shows considerable amount of amorphous débris, probably iron rust. (See index for other analyses.)

No. 173 (276). Flint. July 20, 1895. Microscope shows only indeterminate granules.

No. 174 (265). Grand Rapids. June 19, 1895. Yellowish, alkaline. Microscope shows algæ, diatoms, unicellular plants and animals, inorganic deposit. (See index.)

No. 175 (291). Pontiac. October 25, 1895. Slight milkiness, alkaline. Microscope shows inorganic matter, unicellular plants and animals. (Compare No. 218.)

No. 176 (269). Grand Rapids. June 29, 1895. Yellowish, alkaline. Microscope shows diatoms, algæ, inorganic matter, unicellular plants and animals.

No. 177 (127). Adrian. November 23, 1891. Slightly turbid.

No. 178 (248). Grand Rapids. December 20, 1894. Alkaline. (See index.)

	179 (266). Grand Rapids.	180 (349). Union City.	181 (273). Ann Arbor.	182 (370). Lansing.	183 (175). Ann Arbor.	184 (105). St. Johns.	185 (197). Merrill.
Result of inoculation.	—	—	—	—	—	+	—
Number of bacteria in 72 hours	Liquefaction.	Liquefaction.	Liquefied.	235	30	Liquefied.	10
Nitrites		Tr.				0.00000416	
Nitrates		Tr.	Tr.				Tr.
Albuminoid ammonia	0.000046	0.0000266	0.00004	0.000018	0.000018	.00013	Tr.
Free ammonia	.00002132	.000008	.00002	.00002133	.00002	.000472	0.0000532
Permanganate reduced		.002+	.006	.004	.007	.02464	
Chlorine as NaCl	.013875	.0099	.012	.01485	.00075	.01815	.0043
Organic residue	.120	.120	.130	.100	.030	.148	.055
Inorganic residue	.200	.200	.200	.232	.310	.201	.295
Total residue	.320	.320	.330	.332	.340	.349	.350
Hardness	7.7°	11.°	8.5°	4.8°	16.°	16.5°	8.1°
Sulphates	Tr.	Tr.	Tr.		Tr.		

No. 179 (266). Grand Rapids. June 19, 1895. Yellowish, alkaline. Microscope shows algæ, inorganic deposits, diatoms, large number of unicellular organisms. (See index.)

No. 180 (349). Union City. January 22, 1897. City water supply, probably from driven wells, and is notably weaker than the well water (No. 200). Microscope shows small amount of organic matter.

No. 181 (273). Ann Arbor. July 15, 1895. Probably from wells. Microscope shows inorganic deposit. (See index for other analyses.)

No. 182 (370). Lansing. September 30, 1897. City water supply. Probably principally from wells to the base of the drift. Kedzie gives .271 total solids, of which .157 is organic, .0008 free, and .0001 albuminoid ammonia, with a hardness of 13°. There is probably an error in the hardness given. Opalescent. Microscope shows small amount of organic matter.

No. 183 (175). Ann Arbor. December 1, 1893. From well. Slight milkiness, alkaline. Microscope shows vegetable débris, inorganic matter. (Compare No. 38.)

No. 184 (105). St. Johns. January 17, 1897. Microscope shows crystals of NaCl, bacilli, Draparnaldia, Conferva, Paramecia, diatoms.

No. 185 (197). Merrill. June 22, 1893. Microscope shows a few vegetable fibers. The low degree of hardness of the water from this well for the degree of mineralization is noteworthy and points to the presence of sodic sulphate.

	186 (293). Dowagiac.	187 (247). Grand Rapids.	188 (236). Grand Rapids.	189 (106). St. Johns.	190 (129). Pontiac.	191 (272). Pontiac.	192 (359). Pontiac.
Result of inoculation	—	—	—	—	—	+	—
Number of bacteria in 72 hours	45	700	150	8,464	80	Liquefaction.	68
Nitrites			Tr.	Very f. tr.	Tr.		
Nitrates		Tr.	Tr.		Tr.		
Albuminoid ammonia	0.00001	0.0001	0.000052	0.000122	0.0001	0.000036	0.000018
Free ammonia	.000021	.000012	.00001	.000094	.00018	.000024	.000028
Permanganate reduced			.00001	.11534	.003		.004
Chlorine as NaCl	.00181	.0165	.00713	.01815	.012	.05775	.05675
Organic residue	.130	.070	.080	.132	.130	.050	.140
Inorganic residue	.220	.280	.280	.242	.250	.330	.240
Total residue	.350	.350	.360	.374	.380	.380	.380
Hardness	13.°	11.°	8.°	20.1°	15.5°	9.5°	6.7°
Sulphates	Tr.			.1455			

No. 186 (293). Dowagiac. November 19, 1895. Alkaline. Microscope shows deposit of inorganic matter. This differs from No. 168 mainly in organic matter.

No. 187 (247). Grand Rapids. December 20, 1894. Microscope shows inorganic matter, a few unicellular plants. Alkaline. (See index.)

No. 188. Grand Rapids. September 4, 1894. Microscope shows algæ, infusoria, vegetable fibers, and inorganic matter. Alkaline. (See index.)

No. 189 (106). St. Johns. November 7, 1891. Microscope shows crystals, colorless amorphous matter, diatoms, desmids, germs, navicula, NaCl crystals, fibers.

No. 190 (129). Pontiac. January 16, 1892. From a well, slightly turbid. Microscope shows freshwater algæ. This and the following analyses have a relatively large amount of organic matter.

No. 191 (272). Pontiac. July 1, 1895. Slightly milky, strongly alkaline. Microscope shows unicellular plants and animals, inorganic matter.

No. 192 (359). Pontiac. May 28, 1897. Microscope shows small amount of amorphous matter.

	193 (274). Sherwood.	194 (208). Petoskey.	195 (334). Union City.	196 (137). Holland.	197 (264). Adrian.	198 (371). Battle Creek.	199 (240). Ann Arbor.
Result of inoculation.	+	—	+	—	—	—	—
Number of bacteria in 72 hours	Liquefied	0	Liquefied	20	Liquefaction.	85	.....
Nitrites	0.00004	.....	Tr.	Tr.	.....	Tr.	Tr.
Nitrates	Large amount.	.....	Tr.	Tr.	Ft. tr.	Tr.	.....
Albuminoid ammonia	0.00005	0.000012	0.000024	0.00009	0.000022	0.000014	0.00003
Free ammonia	.00006	.000006	.0000026	.000068	.00001066	.00001	Tr.
Permanganate reduced	.008	.....	.0035	.005672	.....	.002+	.....
Cl. as NaCl	.011	.00246	.01485	.01385	.012375	.330	.00098
Organic residue	.170	.140	.276	.217	.080	.056	.100
Inorganic residue	.210	.240	.112	.173	.320	.402	.320
Total residue	.380	.380	.388	.390	.400	.458	.420
Hardness	12.9°	11.0	13.0	10.5°	10.4°	5.9°	14.0
Sulphates	.....	.00540	Tr.	Tr.	.460	Tr.	Tr.

No. 193 (274). Sherwood. July 15, 1895. On June 20, 1893, a test (198) gave no inoculation effect and but 464 bacteria in 72 hours. This water has an undue amount of organic matter.

No. 194 (208). Petoskey. February 9, 1894. Slight yellowish brown color; reaction alkaline. Microscope shows small deposit of inorganic matter and plant detritus.

No. 195 (334). Union City. September 8, 1896. Opalescent. Microscope shows small amount of organic débris.

No. 196 (137). Holland waterworks, i. e., possibly from driven wells. March 2, 1892. Microscope (100 diameters) shows indeterminate granules; (500 diameters) vegetable fibers, molds.

No. 197 (264). Adrian. June 3, 1895. Yellowish, musty, alkaline. Microscope shows small inorganic deposit. Weakest of Adrian analyses.

No. 198 (371). Battle Creek, city pump. October 5, 1897. Microscope shows very small amount of organic matter.

No. 199 (240). Ann Arbor. November 3, 1894. Alkaline.

	200 (348). Union City.	201 (195). Howell.	202 (343). Mancelona, T. 29 N., R. 6 W.	203 (263). Adrian.	204 (288). Adrian.	205 (267). Grand Rapids.	206 (213). Saginaw.
Result of inoculation.	—	—	—	+	+	—	—
Number of bacteria in 72 hours	Liquefaction.	Countless.	Liquefaction.	Liquefaction.	150	Liquefaction.	Liquefaction.
Nitrites	Tr.	.....	Tr.	.....	Ft. tr.	.....	Tr.
Nitrates	Tr.	Tr.	Tr.	Ft. tr.	Tr.	Very distinct tr.	.....
Albuminoid ammonia	0.0000346	0.00016	0.0000453+	0.000036	0.00012	0.000058	.....
Free ammonia	.0000018	Very ft. Tr.	.0000093+	.000016	.00008	.00001066	.....
Permanganate reduced	.004+	.....	.018—	.....	.....	.....	.....
Chlorine as NaCl	.0299	.000891	.00825	.01815	.0165	.0312	0.00196
Organic residue	.177	.200	.231	.150	.196	.180	.030
Inorganic residue	.253	.250	.231	.330	.284	.340	.500
Total residue	.430	.450	.462	.480	.480	.520	.530
Hardness	14.0	6.0	15.0	10.5°	12.0	7.8°	7.0
Sulphates	Tr.	.....	.....	.68978	Tr.	Ft. tr.	.....

No. 200 (348). Union City. January 22, 1897. From well. Microscope shows small amount of organic matter. (Compare Nos. 180 and 195.)

No. 201 (195). Howell. June 26, 1893. From proposed water supply. Microscope shows a few vegetable fibers, diatoms, etc. Agrees well with Kedzie's analysis.

No. 202 (343). Mancelona. November 14, 1896. From a well. Water similar to the lake water (analysis No. 48). Inorganic, but with less organic matter. Light yellow, opalescent; odor marked. Microscope shows considerable amount of vegetable matter.

No. 203 (263). Adrian. June 3, 1895. Yellowish, musty, alkaline; diatoms, a few unicellular organisms, inorganic matter. There is some error in the amount of sulphates in these Adrian analyses (Nos. 203, 204, 219); charged with decomposing sulphides.

No. 204 (288). Adrian. September 23, 1895. Dirty, yellow, stale, alkaline. Microscope shows large amount of inorganic matter, unicellular plants and animals.

No. 205 (267). Grand Rapids. June 19, 1895. Alkaline. Microscope shows small deposit of inorganic matter.

No. 206 (213). Saginaw. May 26, 1894. Alkaline. Microscope shows small deposit. (Compare No. 213; rather stronger than Saginaw River and yet much less mineralized than Nos. 108–110 and 214.)

	207 (166). Okemos.	208 (85). Gladwin.	209 (177). Kalamazoo.	210 (275). Sherwood.	211 (103). Pontiac (well).	212 (87). Gladwin.	213 (80). Gladwin.
Result of inoculation	—	+	—	+	—	—	—
Number of bacteria in 72 hours	Liquefied	Liquefied	200	Liquefied	265	12	315
Nitrites	0.00055	0.000271	.....	0.00008	.....	.....	Faint tr.
Nitrates	Heavy tr.	.....	Tr.	Large amount.	.....	.....	0.0000192
Albuminoid ammonia	0.00036	0.000102	0.000004	0.00004	0.000368	0.000116	0.000044
Free ammonia	.000158	.00026	.000002	.00003	.000366	.000526	.000374
Permanganate reduced	.1106	.0003614	.00316	.006	.04834	.04424	.0008
Chlorine as NaCl	.0049	.00132	.000825	.035	.04455	.02145	.0118
Organic residue	.270	.211	.030	.350	.280	.125	.153
Inorganic residue	.270	.334	.52	.220	.310	.473	.489
Total residue	.540	.545	.550	.570	.590	.598	.642
Hardness	14.5°	16.5°	11.°	12.°	7.5°	17.°	7.2°
Sulphates	.00582	.002425	.....	.....	.03497	.....	.0388

No. 207 (166). Okemos. November 18, 1892. From well. Microscope shows pigment granules vegetable débris, woody fiber.

No. 208 (85). Gladwin. June 10, 1890. From well with much organic matter. Microscope shows three varieties of crystals, yellow and green amorphous matter, a few germs. (See Nos. 212, 213.)

No. 209 (177). Kalamazoo. October 21, 1893. Alkaline. Microscope shows vegetable débris. (See Index.)

No. 210 (275). Sherwood. July 15, 1895.

No. 211 (103). Pontiac. November 15, 1890. Microscope shows organic débris, brownish yellow amorphous matter, algæ; colorless, odorless amorphous matter and yellow amorphous matter; spherical germs, Oscillatoriæ, Draparnaldia, crystals of NaCl. The large amount of organic matter points to a surface water.

No. 212 (87). Gladwin. July 28, 1890. Microscope (100 diameters) shows vegetable fiber, yellow amorphous matter, crystals; (500 diameters) red amorphous material, yellow amorphous material, many bacilli, crystals, probably NaCl.

No. 213 (80). Gladwin. May 17, 1890. Turbid. Microscope (100 diameters) shows vegetable fiber and reddish amorphous matter; (500 diameters) 4 species of bacteria, a few diatoms, colorless crystals. (See No. 208.)

	214 (228). Saginaw.	215 (99). Parma.	216 (17)0. Bay City.	217 (102). Bay City.	218 (290). Pontiac.	219 (316). Holland.	220 (92). Wyandotte.
Result of inoculation.	+	—	—	—	—	+	+
Number of bacteria in 72 hours	100	1,340	480	780	73	900	2,580
Nitrites	.....	0.000234	0.0023	.....	Tr.	Tr.	0.000247
Nitrates	Tr.	.01143	.005	0.000617	Tr.	Tr.	.01306
Albuminoid ammonia	.00026	.000124	.0000288	.00033	0.0002	0.00006	.00056
Free ammonia	.00004	.00224	.0008	.000176	.000016	.000007	.00046
Permanganate reduced	.....	.01896	.....	.05523	.037	.....	.04108
Chlorine as NaCl	.0099	.10065	.120	.33995	.014025	.08250	.2064
Organic residue	.040	.247	.340	.312	.42	.100	.240
Inorganic residue	.600	.452	.510	.578	.53	.970	.850
Total residue	.640	.699	.830	.890	.95	1.070	1.090
Hardness	2.°	10.5°	7.5°	16.°	6.°	13.°	13.°
Sulphates	Tr.	.3753	0	.01848	Tr.	Tr.	Strong tr.

No. 214 (228). Saginaw. August 11, 1894. From deep well. Note the relatively low hardness and compare with No. 116; probably a rock well. Alkaline. Microscope shows vegetable débris, algæ.

No. 215 (99). Parma. November 28, 1890. The amount of sulphates would be appropriate for a rock well. Microscope (100 diameters) shows fibers, yellow amorphous matter, white amorphous matter, algæ, animalculæ; (500 diameters) fibers, yellow amorphous matter, white amorphous matter, blue spores, short thick bacilli, paramecia, oscillatoriæ.

No. 216 (170). Bay City. March 7, 1893. Granular sediment, alkaline. Microscope shows fungus, spores, and monads.

No. 217 (102). Bay City. November 20, 1890. Microscope (100 diameters) shows fibers, yellow amorphous matter, colorless amorphous matter, germs; (500 diameters) algæ, diatoms, bacilli. Slightly cloudy, slightly musty. The organic matter and sulphates suggest contamination by salt wastes.

No. 218 (290). Pontiac. October 25, 1895. From well. Alkaline; slightly milky. Microscope shows vegetable débris.

No. 219 (316). Holland. May 15, 1896. Milky, alkaline. Microscope shows large amount of inorganic matter. (See index.) This well is probably in the Marshall sandstone, improperly cased.

No. 220 (92). Wyandotte. November 12, 1890. From well. Color, dirty. Microscope (100 diameters) shows crystals, yellow amorphous matter, white amorphous matter; (500 diameters) NaCl crystals, algæ. Yellow and white amorphous matter, precipitated sulphur.

No. 221 (209). Holt. February 9, 1894. Microscope shows deposit of inorganic matter, algæ, and plant detritus in small amount. (Compare Lansing analyses.) This is probably a rock well.

	221 (209). Holt.	222 (262). Adrian.	223 (88). Imlay City.	224 (86). Imlay City.	225 (357). Utica.
Result of inoculation	—	+	—	+	.....
Number of bacteria in 72 hours	2000	Liquefaction.	0	120	.....
Nitrites	Distinct tr.	.....	Ft. tr.	.....	.....
Nitrates	Distinct tr.	Ft. tr.	.....	.....	.....
Albuminoid ammonia	0.00005	0.00011	0.000102	0.000052	0.0000133
Free ammonia	.00003	.0002932	.000462	.00052	.000016
Potassium permanganate reduced	.008	.....	.0082	.000234	.006+
Chlorine as NaCl	.02475	.0528	1.32825	1.321	1.815
Organic residue	.480	.510	.240	.037	.280
Inorganic residue	.740	1.070	1.436	1.648	1.946
Total residue	1.170	1.580	1.676	1.685	2.226
Hardness	2.5°	8.8°	12.°	12.°	10.°
Sulphates	Tr.	1.01784	.....	.21828	.....

No. 221 (202). Adrian. June 3, 1895. Very yellow, foul, alkaline. Microscope shows small inorganic deposit. (See Nos. 203, 204.)

No. 223 (88). Imlay City. July 28, 1890. Microscope (100 diameters) shows red amorphous material, crystals; (500 diameters) cubic crystals, feathery algæ.

No. 224 (86). Imlay City. June 24, 1890. Microscope (100 diameters) shows considerable sediment, yellow amorphous matter; (500 diameters) colorless triangular prisms. A few red spots in the yellow organic matter. Note the large amount of salt in these two analyses; almost certainly from a rock well, perhaps 706 feet deep. (See Geol. Survey Mich., Vol. V, Pt. II, Pl. XXII.)

No. 225 (357). Utica. May 3, 1897. From well. Slightly opalescent. Microscope shows very small amorphous deposit. (Compare with Birmingham analyses.)

MISCELLANEOUS ANALYSES.

Constituent.	226. Owosso.	227. Owosso.	228. Leslie.	229. Chesterfield.	230. Sanford.	231. Hudson.
Al_2O_3	Tr.	(a)				0.00043
$CaCO_3$	*0.160* 9.395	bi. 0.440	bi. 0.525	0.14	0.15	CaO .09747
$CaCl_2$				.13	.98	
$CaSO_4$	*2.988* .051		.121	.15	.76	
Fe_2O_3	Tr.			.01		.00382
$FeCO_3$		bi. .273	bi. .089			
Li_2O						Tr.
$MgCO_3$	*7.125* .121	bi. .327	bi. .180			MgO .0592
$MgCl_2$				.87	1.25	
K_2CO_3			bi. .077			K_2O .00421
SiO_2	*.584* .010	(b) .011	.036			.01972
NaCl	(c) *.630* .016	(c) .036		5.49	16.16	
$NaCO_3$	(c) *.838* .014		bi. .090			Na_2O .02784
SO_3						.02077
Cl						.024
P_2O_5						.00078
Organic			.011			
Total solids	*21.608* .372	1.087	1.079	6.29	19.26	.4081
CO_2			13.5 cu.in.			.36635

a Included with SiO_2. b Including Al_2O_3. c Including the corresponding potash salt.

No. 226. Owosso, city supply wells. Dearborn Drug and Chemical Works, analyst, for E. F. Dudley. This analysis checks quite closely with No. 100 by Kedzie; No. 227 is somewhat stronger, more like the Eaton Rapids waters, and very like the Leslie magnetic, No. 228, and is, therefore, probably from a well in the Coal Measures.

No. 227. Owosso, chalybeate. Given by A. C. Peale, Bull. U. S. Geol. Survey No. 32, p. 149.

No. 228. Leslie magnetic wells. Given by Peale, op. cit., R. C. Kedzie, analyst. There are a number of flowing wells in the Coal Measures, both at Owosso and Leslie, from which the two analyses just mentioned probably come.

No. 229. Section line between sections 2 and 11, Chesterfield Township (T. 3 N., R. 14 E.). From report of Douglas Houghton, State geologist, 1838, p. 29, and Winchell, 1861, p. 186. Sp. gr. 1.0057. (Compare the Salutaris (No. 310), Wales (No. 122), Utica (No. 225), and Birmingham (No. 235) analyses, waters of the Berea grit.)

No. 230. Sanford. Sec. 26, T. 15 N., R. 1 W. This very old analysis is probably of water from the State salt well, and the amount of earthy chlorides seems likely to be erroneous. Sp. gr. 1.0132. (Same references as No. 229.)

No. 231. Hudson "Zauberwasser." Analysed for Dr. George Chapman by A. B. Prescott in 1881.

The total of the bases and acids amounts to 0.62454; this excess over the total solids as given, which is the residue found constant at 220° F., is mainly accounted for by the free CO_2 (0.20795 parts per thousand).

WATERS FROM BEDS ABOVE THE MARSHALL FORMATION.

Constituent.	232. Bayport.	233. Bayport.	234. Agricultural College.	235. Agricultural College.	236. Agricultural College hydrant.	237. Agricultural College purifier.
$CaCO_3$	*10.36* .148	bi. 0.344	*10.60* .151	0.206		
$CaSO_4$	0	.019		Tr.		
Fe_2O_3			.40 .006			
$FeCO_3$		.009		.022		
$MgCO_3$	*2.14* .031		*4.97* .071	.078		
MgCl		.016				
KCl				Tr.		
Silicic acid		.010				
NaCl	*.50* .007	.022		Tr.		
$NaCO_3$		bi. .078				
Organic	*1.00* .014				*7.09* .101	*2.727* .390
Total	*14.00* .200	.499	*15.970* .228	.325	*22.756* .321	*7.729* .110
Temporary hardness	12.°				3.32°	1.17°
Permanent hardness	6.5°				3.30°	1.78°

Constituent.	238. Lansing.	239. Lansing (artesian well).	240. Lansing (condensed milk factory).	241. Lansing (Americanus spring.)	242. Lansing (magnetic spring).
$CaCO_3$	*10.80* .154	*11.00* .157	*22.00* .314	*103.086*	bi. 1.537
$CaSO_4$	0		0		
Fe_2O_3	*.25* .004	*.50* .007	*.50* .007		
$FeCO_3$				*3.681*	bi. .027
LiCl				*.101*	
$MgCO_3$	*5.95* .085	*2.70* .039	*4.00* .057	*bi. 30.560*	bi. .329
Nitrites	0				
Nitrates	Tr.				
K_2SO_4				*14.94*	.213
SiO_2	*1.00* .014	*.50* .007	*.50* .007	*3.96*	.057
NaCl	*1.00* .014	*.300* .004		*220.224*	4.575
$NaCO_3$			*a 3.00* .043	*bi. 112.08*	bi. 1.601
Na_2SO_4					.429
NaBr				*30.065*	
Organic	*4.00* .057	*2.920* .042	*25.00* .357		
Total solids	*23.00*	*17.92* .256	*55.00* .786		8.768
Temporary hardness	13.°		1.°		
Permanent hardness	7.°		4.°		
Free ammonia	.00008				
Albuminoid ammonia	.0001				
O from permanganate	*.50* .007				

a Plus KCl.

Analyses Nos. 232 to 240 were all prepared by R. C. and F. S. Kedzie, except Nos. 236 and 237, the averages of partial analyses by a class of ten of their students, and No. 233, which was made by A. B. Prescott. No. 232 was given incorrectly in Geological Survey Michigan, Vol. V, Part II, 1895, page 32. The sample is from a well near the Bayport Hotel, and the analysis is given inaccurately on its circulars. The well goes down 15 feet into a bed said to be sandstone, which must be one of the sandstones associated with the Bayport limestone of the upper Grand Rapids series, since the outcrops on the bluff near by are limestone.

No. 233 is of water from the Bayport station, September 19, 1891. Analyst, A. B. Prescott, for W. L. Webber. Reaction faintly alkaline. The residue of half a liter was tested for K, Li, and Br. Saline solids determined directly were 0.5006 per thousand.

These two analyses resemble each other in the small amount of magnesia. The Bayport limestones are usually quite low in magnesia.

No. 234 is of water from the Agricultural College well, October 9, 1891. Furnished by Professor F. S. Kedzie.

No. 235 is an analysis of water from the same well, cited in an article on boiler water purification by Prof. R. C. Carpenter (Transactions Am. Soc. Mech. Engineers, Vol. XI, p. 939), in which the well is said to be 260 feet deep. As a matter of fact, Professor Weil assures me that but one well, 470 feet deep, has been used. Another well, just sunk (1899) to 325 feet, found flowing water at a less depth. Professor Carpenter probably refers to depth of chief stream. L. J. Lincoln's record of the well and a full history of it are left to a later paper. It probably draws water both from the Marshall and beds above.

No. 236 is of the same water drawn from the hydrant, and is the average of analyses by ten students.

No. 237 is of water taken from the purifier, and shows the effect of aeration and heating nearly to boiling in precipitating the lime and reducing the hardness.

Nos. 235 and 236 agree well in total solids, and the variation in No. 234 is probably due partly to different conditions of pumping and partly to different points of sampling. Analyses 172A and 172B in the Appendix show that such variations make appreciable differences.

No. 238 is of the Lansing city supply, which is obtained from wells of various depths, 40 to 150 and more feet deep. It is one of a series of analyses made every year by Professor R. C. Kedzie. The analyses are all similar, though the total solids may be as low as 19 grains per gallon. This analysis was made July 3, 1893, and indicates very good water. It is hard, however, and was so heavily bicarbonated that toward the end of the system dead ends of the pipes became highly charged with iron.

No. 239 is of water from an artesian (i. e., flowing) well in Lansing, which is not specified. There are a number of wells, generally about 200 feet deep, which have flowed. (See records in a later paper.)

No. 240 is of water from the deep well of the condensed-milk factory at Lansing, the record of which is known, so that it is certain that none of

the Marshall water is included (as may be the case in other wells). The water is probably almost entirely from the Parma sandstone—Bayport limestone horizons—as the relatively high percentage of lime shows.

No. 241 is an analysis made in Chicago in 1893, of water from the old mineral well of Lansing. It is still advertised as 1,402 feet deep, which was the original depth of the well; I am informed, however, that the water was originally quite salt; that the well is plugged about 500 feet down, and cased probably only 57 feet—just to bed rock. Before I had learned these facts, however, this analysis and No. 242 were sufficient to show such a state of affairs, for waters so strong in lime, relatively to salt, point to the limestones as partially their source. The CO_2 (235.55) is added artificially.

No. 242 is an older analysis by Dr. Jennings, taken from Peale, Bulletin U. S. Geological Survey No. 32, page 148. It is from the same well as the water of analysis No. 241, which has been variously known as Lansing magnetic, Michigan Congress, and Americanus. The casing and plugging may, however, have varied.

EATON RAPIDS, MIDLAND, PORTSMOUTH, BAY CITY, AND SAGINAW SPRINGS AND WELLS.

Constituent.	243. Frost well.	244. Mosher spring.	245. Sterling spring.	246. Shaw spring.	247. Bodine spring.	248. Midland magnetic spring.	249. Midland mineral spring.
$Al_2(P_2O_5)_2$	.....	.....	.....	.....	.....	0.025	*1.73* / .0247
$CaCO_3$	0.661	0.333	.....	0.356	bi. 0.692	.....	.....
$CaCl_2$	.....	.....	.....	.....	.....	.089	*6.22* / .089
$CaSO_4$	.066	.775	0.945	.827	.983	.064	*4.46* / .0637
$FeCO_3$	.034	bi. .017	.048	bi. .038	bi. .039	.....	.....
$MgCO_3$	.130	.077	.....	.066	bi. .144	.....	.....
$MgCl$	.....	.....	.....	.....	.....	.031	*2.19* / .031
$MgSO_4$	.....	.....	.161	.....	.....	.....	.....
K_2SO_4	.....	.....	.....	.....	.....	1.174	*32.190* / .460
KCl	.....	.....	.....	.....	.....	Tr.	.....
K_2CO_3	.....	.020	.....	.022	bi. .052	.....	.....
SiO_2	.225	.044	.....	.024	.034	.042	*2.96* / .042
$NaCl$	.132	.015	.089	.015	.026	.....	*33.70* / .467
Na_2CO_3	.....	.092	.....	.198	bi. .087	.467	.....
Na_2SO_4	.....	.....	.216	.....	.....	.315	*27.07* / .315
Loss	.....	.....	.....	.....	.....	.046	*3.21* / .046
Organic	.013	.015	.....	.015	.....	.035	*2.47* / .035
Total solids	1.260	1.388	1.460	1.559	2.057	2.288	*110.20* / 1.574
CO_2	22.22	15.38	.....	15.97	17.35	.....	.....

Constituent.	250. Midland.	251. Portsmouth (664-foot well).	252. Bay City (Gilmore 505-foot well).	253. East Saginaw (575-foot well).	254. East Saginaw (617-foot well).	255. East Saginaw (617-foot well).
$CaCO_3$	0.8924					
$CaCl_2$		3.472	5.302			5.37
$CaSO_4$	.5832	4.884	3.961			2.25(?)
$Fe_2O_3 + Al_2O_3$	.320					
$MgCO_3$	.005					
$MgCl$		4.333	4.115		4.41	12.41
$MgBr$					Erroneous.	
KCl	Tr.					
SiO_2	.19					
$NaCl$	7.373	125.315	152.674	139.0	194.4	190.88
Total solids	9.0778	138.004	166.052	158.2		210.91

Analyses Nos. 243 to 247 are of waters from a group of wells in Eaton Rapids. A record of the strata met in one is on file and will be given in a later paper, but the chemical variation in the waters indicates that there must have been some differences in casing or depth at the time the analyses were made. These are taken from Peale (op. cit., page 147).

No. 243 is of water from the Frost well; S. P. Duffield, analyst.

No. 244 is of water from the Mosher spring (i. e., flowing well?); R. C. Kedzie, analyst.

No. 245 is of water from the Sterling spring or flowing well; C. T. Jackson, analyst.

No. 246 is of water from the Shaw spring or flowing well; R. C. Kedzie, analyst.

No. 247 is of water from the Bodine spring or flowing well; R. C. Kedzie, analyst.

The large amounts of carbonate of lime and iron are characteristic of the waters of these wells. Nos. 227 and 228, waters from Owosso and Leslie, will be recognized as belonging to the same group, although objective evidence of the fact is weak. The Lansing and Midland analyses (Nos. 241, 242, 248, and 249) all have the same character. The presence of potash is less uniformly noted, but this may be due to defective analyses. The fire clays of the Coal Measures are, however, very low in potash, so that one could not expect to find this element prevalent in the mineral waters. Perhaps it has been leached out into the mineral waters, and the concentration previous to the formation of the Coal Measures which deposited the gypsum of the Grand Rapids series may have left the potash more than usually abundant afterwards.

No. 248 is an analysis of the Midland magnetic water, cited by Peale (op. cit.), and is probably from the same well, possibly differently cased, as the water of the following analysis, but most likely is merely

a different version of the same analysis, as only the K_2SO_4 differs materially in the two analyses.

No. 249 is an analysis by Dr. S. P. Duffield of water from the Midland mineral springs. Well said to be 400 feet deep and probably cased 200 feet deep, i. e., to bed rock. These should be compared with other analyses of wells of various depths at Midland. The discussion of the rock records and varying salinity of the waters at Midland must be left to a later paper.

No. 250 is of the overflow water of the casing of the Midland Chemical Company's well No. 3, January 20, 1895. Analyst, J. E. Graves. The stream of water which has forced itself up outside the casing and, overflowing, yielded the sample analyzed, is supposed to come mainly from between 300 and 600 feet in depth, i. e., from the upper Coal Measures at about the level from which samples Nos. 248 and 249 were taken. The temperature as given, 55° F., agrees with this. On November 2, 1897, qualitative tests of this water showed a specific gravity of 1.030. Tests of water flowing from abandoned salt wells gave—from Foster's Block—specific gravity 1.012; and from 1¾ miles west of town 1.014, all overflowing with a strong current, and strong in salt and sulphates. Presumably, therefore, No. 250 is very largely but variably from lower levels than Nos. 248 and 249.

No. 251 is of water from a Portsmouth (part of Bay City) 664-foot well, with a 54° salinometer brine. Analyst, C. A. Goessmann. This and the following analysis are commercial analyses taken from Geological Survey Michigan, Vol. III, Pt. I, page 182. They serve to show that the tendency to a high percentage of sulphates continues to be characteristic of the waters above the Marshall, even in the deeper brines which have been used for salt manufacture.

This fact, so far as I know, was first remarked by Garrigues, from whose report the analyses are cited, and is entirely natural in view of the prevalence of gypsum in the Grand Rapids series, and of pyrite in the coal.

No. 252 is of water from the Gillmore well, 505 feet deep, at Bay City. Analyst and authority, same as for No. 251. Strength, 65° salinometer.

Nos. 253 to 255 are cited from A. Winchell's report of the State geologist, 1861, and are of water from the first salt well sunk by the East Saginaw Salt Company.

No. 253 is of the water when the well was 575 feet deep. Specific gravity, 1.110; 64° salinometer. Analyst, Dr. Chilton. 1,155 grains of solids and 1,014.57 grains of NaCl in a wine pint. (Op. cit., p. 170.)

No. 254 is of the water when the well was 617 feet deep. Specific gravity, 1.172 grains; 86° salinometer. Analyst, Dr. I. G. Webb. 1,416 grains of NaCl and 32 grains of other chlorides in a wine pint.

No. 255 is of the same water as No. 254, and by the same analyst.

It is hardly worth while to reproduce all Dr. Houghton's analyses of

brine spring waters in his report of 1838, because of their early date. In Huron County the boundary of the sulphated waters above the Marshall is very sharp, the change from waters giving a strong reaction for sulphates to those giving no reaction coming within a mile. In the southern part of the coal basin gypsum deposits are not struck in the wells and the waters are less sulphated, being chalybeate carbonated waters low in magnesia, not unlike those from the drift.

WATERS FROM THE MARSHALL FORMATION.

Constituent.	256. Badaxe No. 1.	257. Badaxe No. 2.	258. Grasmere.	259. Oak Grove.	260. Bayport. 328-foot well.	261. Old Bayport well.
Al_2O_3						
$CaCO_3$			.171	bi. *14.053* .241	bi. *9.2141* .038	*26.5262* .454
$CaCl_2$			Cl.0025			
$CaSO_4$		0.0		*13.703* .234	*25.6405* .440	*20.9813* .360
Fe_2O_3				Al_2O_3 *.583* .01		
$FeCO_3$					*.2570* .044	
LiCl				Tr.		
$MgCO_3$				bi. *12.145* .208	bi. *5.2245* .100	
MgCl				*1.253* .021		*11.5630* .198
$MgSO_4$						
KCl				*2.973* .051		
SiO_2				Tr.	*.3412* (a). 144	*.3598* (a). 015
NaCl				*98.363* 1.685	*53.9743* .925	*138.7109* 2.379
$NaCO_3$					*11.7249* bi. .201	
Inorganic	*16.45* .235	*14.30* .204				
Organic	*7.000* .100	*6.300* .090				
Total solids	*23.45* .335	*20.650* .295		*143.075* 2.506	*110.4764* 1.892	*198.6412* 3.403
Hardness	5°.9	5.2°	10.0			
Free ammonia	.0000024	Slight tr.				
Albuminoid ammonia	.000072	.000048				
Loss						

a Silicic acid.

It is not at all certain that water above the Marshall is not admitted to many of the wells represented in these analyses. Even where the

upper water is supposed to be cased off there may be leaks in the casing. As a whole, however, the analyses show very well the characteristics of the formation. One feature which deserves special attention is the freshness of these waters—i. e., low amount of mineral matter for a given depth—compared with those of other horizons.

No. 256 is of the Badaxe water supply, which comes from artesian wells, whose record is known, over 200 feet deep in the Marshall. Partial analysis by F. S. Kedzie in 1897. This and the following analysis were made because of complaint regarding the excessive growth of algæ. This sample was taken at the pump, while sample No. 257 was taken from the dead end of a pipe. In this respect they correspond to 172A and 172B. In both cases, the sample taken farthest from the pump contains the greater amount of matter, both organic and inorganic. Suggested remedies are frequent—flushing and covering the standpipe so as to exclude light. F. S. Kedzie also suggested that the reaction of $CaSO_4$ with organic matter might produce H_2S and add to the disagreeable character of the water, but it is doubtful if $CaSO_4$ exists appreciably in the Badaxe water. Qualitative tests failed to reveal it.

No. 258, Grasmere, is of water "from a coarse-grained gray sand rock reached at 40 feet and extending 138 feet, rising to 8 feet above the surface." Analyst, A. B. Prescott, for W. L. Webber. Qualitative tests showed Ca, Mg, Na, Al, SO_3, CO_2, Fe not more than a trace.

No. 259 is of water from the Oak Grove mineral well at Flint, 265 feet deep, flowing about 9 gallons per minute. Analyst, J. E. Clark. Original statement in grains per United States gallon. There are only 39 feet of casing, and water comes in above the Marshall, as the amount of $CaSO_4$ shows.

No. 260 is of water from a well 328 feet deep near the Bayport House, Bayport. A. B. Prescott, analyst for W. L. Webber. The water said to be found in a coarse gray sand rock (upper Marshall) at the bottom (below 250 feet), but the analysis indicates that the upper waters are not altogether excluded. This is the flowing well just north of, but quite a little below, the hotel. The temperature of 47° F. is said to be the same throughout the year. Specific gravity, 1.0017. Reaction faintly alkaline. Analysis, as given in table, as combined from CaO 0.1933, MgO 0.0421, NaO 0.5583, FeO 0.0027, SO_3 0.2582, Cl 0.6389, CO_2 0.1264, SiO_2 0.0111, total 1.8310. A similar well lies close to the bay and just west of the railroad track.

No. 261 is of water from the Old Bayport well. This was a well for salt, 1,900 or more feet deep; when plugged at 750 feet the water was still salt, but when plugged at 550 feet it was a potable water, presumably the one analyzed. Analyst, A. B. Prescott, for W. L. Webber. Reaction faintly alkaline. Specific gravity, 1.0029. The constituents are combined from CaO 0.2978, MgO 0.0835, NaO 1.2900, SO_3 0.2110, Cl 1.5850, CO_2 0.2358, SiO_2 0.0113, total 3.7144.

No. 262 is of water from Butterworth's magnetic spring, Grand Rapids. S. P. Duffield, analyst. Mr. Powers says that this well draws mainly from the upper 18 feet of the Marshall sandstone—i. e., 261–274 feet of the record given by Winchell—and that the water contains more $CaCl_2$ than the water of his well—the Arcade—which draws from the lower 18 feet of the Marshall—i. e., 295 to 300 feet from the surface. This would apply better if we took No. 262 to be the analysis of the Arcade well water, low in $CaCl_2$, and No. 263 to be the analysis of water from the top of the Marshall, from which, indeed, it is derived. The constituents other than the NaCl and the $CaCl_2$ are remarkably similar.

No. 263 is of water from the original test well, Scribner's, at Grand Rapids, October 14, 1859. Analyst, Prof. L. R. Fisk. Specific gravity, 1.01752. Biennial report of State geologist, 1861, pages 146, 167, 186, and Geological Survey Michigan, Vol. III, Part I, page 180. The water at 248 feet depth is reported as fresh, but there are saline streaks at 82 feet and at 140 feet, so that probably most of the salt, etc., comes from that section.

Nos. 264 to 266 are of waters from wells within a few miles of each other, analyzed by the same chemist, and, as the record of one and the date concerning the others show, drawing chiefly on the Marshall sandstone at 179 to 250 feet depth.

No. 264 is from Peale, Bulletin U. S. Geological Survey No. 32, page 148.

No. 265 is from Peale, loc. cit. I also have an independent version of the analysis, giving 0.1808 bicarbonate of lime; trade name, "Attapah;" specific gravity, 1.0064. Temperature, 52° (Peale), or 50° F.

No. 266 is also taken from Peale, or from Geological Survey Michigan, Vol. V, Part II, 1895, page 60. Temperature, 48°.

I would not lay too much stress upon the presence of Br, Li, etc., in the foregoing group of analyses, for much depends on whether the chemist looked for them. Yet the presence of bromine is interesting in connection with its undoubted presence in abundance in the Marshall brines of the center of the basin. The absence of $CaSO_4$ is noteworthy, also the prevalence of chlorides and bromides of calcium and magnesium over other salts.

Constituent.	262. Grand Rapids (Butterworth).	263. Grand Rapids (original).	264. Grand Haven.	265. Springlake (Attapah).	266. Fruitport (iron magnetic).
Al_2O_3	0.007	.....	0.009	Tr.	Tr.
NH_4Cl	.....	.....	.....	0.0003	.....
$CaCO_3$	.143	0.0473	.035	bi. .002	bi. 0.087
$CaCl_2$	.010	2.764	2.557	1.944	1.903
$CaSO_4$	1.288	1.312	.....	.....	.....
CaF_2	.....	.....	.001 (?)	.....	.....
$FeCO_3$	.017	.0145	.001	bi. .017	bi. .129
Li_2CO_3	.....	.....	.....	Tr.	.....

Constituent.	262. Grand Rapids (Butterworth).	263. Grand Rapids (original).	264. Grand Haven.	265. Springlake (Attapah).	266. Fruitport (iron magnetic).
$MgCO_3$	0.100	0.0084	0.027	Tr. 0.001	Tr. 0.071
MgCl	.718	.7196	1.065	.619	.803
MgBr	.....	.....	.005	.037	.013
MgI	.....	.....	.001	.....	.....
$MnH_2(CO_3)_2$	.....	.....	.....	Tr. .001	Tr. .002
KCl	.168	.1561	.033	.073	.007
K_2CO_3	.....	.....	.049	.....	.....
SiO_2	.009	.0025	.018	.009	.182
NaCl	.218	17.3696	5.311	6.950	7.950
$NaCO_3$	.086	.....	.038	bi. .003	bi. .113
$NaSO_4$	.....	.....	1.190	.799	.789
Organic	.....	a .8841	.....	.314	.....
Total solids	2.871	23.3385	10.431	10.766	12.048
CO_2	.....	b .0603	.....	.....	7 cu. in.
Loss	.011	.....	.....	.....	.....

a Loss. b Free.

SAGINAW RIVER SALINE WELLS.

Constituent.	267. East Saginaw Salt Mfg. Co., (Oct., 1862).	268. Swift & Lockwood.	269. East Saginaw (Apr. 10, 11, 1860).	270. T. N. Whittier.	271. East Saginaw.	272. Oneida Salt Co., Zilwaukee.	273. Bangor Salt Mfg. Co.
$CaCO_3$	.....	.....	.....	.....	0.500	Tr.	.....
$CaCl_2$	22.665	26.430	21.42	.....	32.873	26.23	29.611
$CaSO_4$	1.516	.983	1.16	.....	.982	.80	.722
$FeCO_3$	.....	.....	1.05	.....	.116	.054	.....
$FeCl_2$	.....	.....	.....	.....	.....	.032	.....
$MgCO_3$	.....	.....	.....	.....	.....	Tr.	.....
MgCl	9.629	10.685	15.22	.....	17.743	13.43	12.612
MgBr	.....	.....	.....	.....	.....	Tr.	.....
KCl	.....	.....	2.20	.....	.....	.....	.....
$Al_2O_3+SiO_2$	.....	.....	.....	.....	.245	.....	.....
NaCl	168.636	175.103	179.12	.....	168.710	193.04	198.595
NaBr	.....	.....	.....	.....	.401	Tr.	.....
Organic	.....	.....	.....	.....	.65	3.724	.....
Total solids	a 202.446	a 213.201	a 220.17	.....	b 221.570	b 237.31	a 241.54
Specific gravity	80.°	86.°	90°=1.179	92°	90°=1.177	1.1864	1.1771
CO_2	.....	.....	.....	.....	.....	Tr.	.....

a By addition. b Direct determination.

Analyses No. 267 et seq. show much stronger waters. Such a sharp line does not exist in nature, but is due merely to the fact that man wants waters either weak enough to be drinkable or as strong as possible.

No. 267 is of water from the East Saginaw Salt Manufacturing Company's well when 806 feet deep. Analyst, C. A. Goessmann. October, 1862. Geological Survey of Michigan, Vol. III, 1876, Part I, page 183. Total obtained by addition.

No. 268 is of water from Swift & Lockwood's well, 860 feet deep, at Saginaw. Same analyst and date as No. 267. Total obtained by addition.

No. 269 is of water from the East Saginaw Salt Manufacturing Company's well when 636 feet deep. Prof. S. H. Douglass, analyst. April 11, 1860. Same reference as No. 267, and also biennial report of the State geologist, 1861, pages 171 and 186. Total obtained by addition. April 16, specific gravity, 1.170. As No. 269 is stronger than No. 267, which is of a water with deeper source, an admixture of the upper waters—that is, leaky casing when the water for No. 267 was drawn—is suggested, especially since the weaker water is stronger in sulphates.

Sample No. 270, from Saginaw River, specific gravity 92°, was left for an analysis, not yet reported, by T. N. Whittier.

No. 271 is an analysis of the same water as Nos. 267 and 269, the well being 649 feet deep. Analyst, Dr. Chilton. May, 1860. Reported by W. L. Webber in the biennial report of the State geologist, 1861, pages 171 and 186. It agrees quite well with previous analyses and reports, the bromides probably overlooked by the others. Total directly observed.

No. 272 is of water from the well of the Oneida Salt Company, Crow Island, Zilwaukee. Analyst, H. C. Hahn. Geological Survey of Michigan, Vol. III, Part I, page 185. Total directly observed.

No. 273 is of water from the Bangor Salt Manufacturing Company's well at Banks, Bay City. Well 774 feet deep. Analyst and references the same as No. 267.

BRINES OF THE MARSHALL SANDSTONE.

Constituent.	274. Michigan Solar Salt Co., Zilwaukee.	275. Buffalo Salt Mfg. Co., East Saginaw No. 1.	276. Buffalo Salt Mfg. Co., East Saginaw No. 2.	277. New York Solar Salt Co., Zilwaukee.	278. A. L. Clark's well, Big Rapids.	279. Bay City No. 1.	280. Bay City No. 2.
$CaCO_3$	0.010	.....	.....	0.010	.....	.....	.....
$CaCl$	29.16	24.106	24.321	30.40	46.40938	33.878	32.556
$CaSO_4$	.82	1.028	1.038	.73	.47316	.689	.691
$FeCO_3$	.123	.119	.123	.058	.06354	.856	1.292
$FeCl_2$	.....	.....	.....	.038	.....	.....	.....
$MgCO_3$	.015	.....	.....	.006	.....	.....	.....
$MgCl$	13.81	10.803	8.744	14.19	19.79204	13.783	13.779
$NaBr$	.....	Tr.	Tr.	1.2374	1.2374	.....	.....
H_2SiO_3	.....	.....	.....	.....	.00108	.....	.....
$NaCl$	196.71	187.764	189.472	199.14	185.69219	202.945	204.204
Organic or loss	loss 2.20	21.104	21.226	5.02	.....	14.518	14.147
Total solids	242.85	*a* 244.924	(*b*)	*c* 249.58	*d*253.66878	*a* 266.669	(*b*)
Degrees salinometer, or specific gravity	1.1900	1.1771	.....	1.1930	1.205	1.1989	.....
CO_2	.....	.....	.....	.....	.....	.....	.....

a Average of No. 1 and No. 2. *b* See No. 1. *c* Direct determination. *d* By addition.

No. 274. Michigan Solar Salt Company, Zilwaukee. Analyst and references the same as No. 272.

No. 275 and No. 276 are duplicate analyses, cited from the unpublished thesis "Saginaw Salines: a short sketch of their history and source; of the methods of obtaining them; of the processes used in the manufacture of salt from them; together with analyses of representative specimens," by John Ayres, Ann Arbor, June, 1880, of which an abstract from the copy in the general library of the University of Michigan was made for me through the kindness of Professor Prescott. For this analysis and probably the others by Mr. Ayres the specific gravity was taken at 20° C., the total residue by drying at 110° to 115° C. In No. 275 the total Cl in 25 cubic centimeters brine was 4.043.

No. 277 is of water from the well of the New York Solar Salt Company at Zilwaukee. Analyst and reference the same as No. 272.

No. 278 is of water from the Red Cross well at Big Rapids, A. L. Clark original owner. Depth, 1,400 feet. Analyst, A. B. Prescott. The published statement is in grains per United States gallon at 62° F.—i. e., United States gallon=70,277.19 grains. The following is the statement of bases and acids: NaO 98.95923, MgO 8.35636, CaO 3.66594, FeO 0.03944, SiO_2 0.00073, Cl 156.97050, Br_2 0.96057, SO_3 0.27833, CO_2 0.02415=289.23289, which, less oxygen not in the salts and plus the water of silicic acid 35.56590, gives the tabulated footing.

A sample from a drug-store gave specific gravity 1.156 with 0.75 Br. When I tested it, December, 1895, the specific gravity was 1.202. The water is said to have been struck at 1,300 feet and to have had at first the specific gravity 1.229. The mineral strength is thus lasting very well.

Nos. 279 and 280 are duplicate analyses of representative Bay City brine, obtained through S. S. Garrigues. Analyst and reference the same as No. 275. In 25 cubic centimeters brine was 4.6496 Cl.

BRINES AT MIDLAND.

Constituent.	281. Midland No. 1.	282. Midland No. 2.	283. Midland bittern No. 1.	284. Midland bittern No. 2.
$CaCl_2$	86.666	88.760	143.574	145.859
$CaSO_4$	.199	.220	.160	.160
$FeCO_3$	1.144	.954	.....	.....
MgCl	24.665	24.109	39.263	34.019
$MgBr_2$	8.771	8.771	48.356	48.356
NaCl	148.984	147.599	56.754	60.801
Total solids	304.750	366.059	.....	.....
Loss	34.321	34.337	77.952	76.864

Nos. 281 and 282 are duplicate analyses of Midland brine, Harris Brothers' well, 1,300 feet deep, flowing 30 gallons a minute. Analyst and reference the same as No. 275. In 25 cubic centimeters brine was 0.2340 Br and 5.0414 Cl. See also Geological Survey Michigan, Vol. V, Part II, page 69. The specific gravity and total solids do not seem accordant, since the total solids would imply a higher specific gravity. The Larkin & Patrick well at the same depth is said to have had strength of 115° salinometer (1.239 specific gravity), and the Dow (Midland Chemical Company) well has 1.235 specific gravity.

Nos. 283 and 284 are of bittern left after the crystallization of salt from the same well as Nos. 281 and 282. Same analyst and reference. Published also by Rowland, Tenth Census of the United States, Vol. II, p. 22. See also Geological Survey Michigan, Vol. V, Part II, page 35, and note corrected NaCl. In 25 cubic centimeters was 1.32 Br and 4.8869 Cl. "In the estimation of Br by Mr. Ayers, this element was expelled by treatment with excess of chlorine during evaporation to dryness, then obtaining the total of silver chloride in ratio of the weight of mixed silver chloride and bromide from the brine"—not a very accurate method. Note the large amount of loss when total solids are independently and directly determined. This shows that ammonium and potassium chlorides and other constituents have not been determined. Potassic chloride is made from the Marshall brines by the North American Chemical Company at Bay City. Mr. Ayres's chemical work was done under Prof. H. W. Cheever about three years before the writing of "Select methods of qualitative analysis."

An analysis of the water from the Alma Sanitarium Company's well was made by Prof. C. A. Davis, May 5, 1889. Said to be almost a pure Marshall sandstone water. The published form was inaccurate, and I am not able to give corrected figures. The analyses given in a later section (Nos. 325 to 327) show the lower water and the two waters mixed.

In the above group of analyses the characteristics of the Marshall waters are well defined—i. e., the excess of Cl so as to be far more than to satisfy the soda; or, as Garrigues says, a "decrease in percentage of gypsum, an increased percentage of the earth chlorides, and an increased quantity of salt."

Numerous qualitative tests have convinced me that the sulphates are often from higher beds, and for a given depth the Marshall is less mineralized than the beds above or below. It is not charged with gases to any marked extent.

As soon as we leave the porous upper Marshall and get down to the boundary between it and the Coldwater—that is, the lower Marshall—the beds are likely to become saline again. For instance, S. O. Hickok, of Allen, Hillsdale County, Michigan, has a well 221 feet deep, which yields 277.04 grains NaCl and 33 of $CaSO_4$ per gallon. I have numer-

ous other qualitative tests that show the same thing. But on the whole, between the Marshall and the Berea grit the strata are dry and the waters do not merit a separate section.

WATERS FROM THE BEREA GRIT.

Constituent.	285. Birmingham.	286. Ann Arbor.	287. White Rock.	288. East Tawas.	289. Port Austin.	290. Sand Beach.	291. Oscoda.
$CaCO_3$	0.10205	.....	.....	.....	.....	.....	Tr.
$CaCl_2$	.....	24.53	5.373	34.843	31.274	3.000	42.100
$CaSO_4$	.....	.....	2.623	.350	.129	2.539	Tr.
$FeCO_3$	.0049	*a* 4.381	*b* .0032	.....	.....	.....	.....
$MgCO_3$	.0645	.....	.....	.....	.....	.....	.....
$MgCl$	.....	6.95	4.106	12.433	15.675	1.591	19.3
KCl	.03156	.....	.....	.....	.....	.....	.....
SiO_2	.0206	.....	.....	.....	.....	.....	.....
$NaCl$	2.27256	138.96	189.102	156.141	176.161	225.673	179.300
Na_2CO_3	.15558	.....	.....	.....	.....	.....	.....
$NaNO_3$	.00122	.....	.....	.....	.....	.....	.....
Organic	.03546	.....	.....	.....	.....	.....	.....
Total solids	2.70453	174.8	201.236	203.767	223.239	232.803	241.9
Salinometer	.....	68.°	78.5°	85.°	88.°	284.°	90.°

a As oxide? *b* FeO.

The well at Utica, with 2.226 ounces per cubic foot solids, probably obtains water from the Berea; the only sample of potable water, however, of whose geological horizon we are certain, independent of the analyses, is No. 285. Kedzie's analysis of the Wales water comes next. Some idea of the composition of the Berea brine at Ypsilanti may be obtained by comparing the analyses of the Ypsilanti wells (Nos. 304 and 305), in the first of which the higher water is cased out and in the second admitted. We see that the water from the Berea is extra strong in NaCl and is a very pure brine.

No. 285 is of water from the new well on the farm of J. R. Cooper, Birmingham. No. 2, about 1,500 feet southwest of the first well, which was about 20 feet above the swamp, the water rising to about 16 feet from the top; No. 1 also contained more chlorides and less carbonates.

There is an excess of CO_2, probably in the form of bicarbonates, present in the water, and the organic matter and loss does not include this, but does include the CO_2 with the iron. Analyst and informant, George L. Heath.

No. 286 is of water from the Ann Arbor deep well, of which there are two accounts. According to Rominger (Geol. Survey Michigan, Vol. III, 1876, Part I, p. 92), the brine from the sandstone 333 feet down—i. e., from the Berea grit—has a specific gravity of 1.142, and 19 per cent residue by evaporation, "almost pure chloride of sodium." Winchell, in his Geology of Washtenaw County (Chicago, 1881, p. 26), gives the strength as 68° salinometer, corresponding to a specific gravity of 1.131 and 17.48 per cent salt; he also gives an analysis of the residue, and putting the

two together we obtain the figures of the tabulated analysis. Illuminating gas also escapes, and is also reported from a well at Blackmar which reaches this horizon.

No. 286A of the Appendix is a recent analysis, by J. E. Clark, of water from the Ypsilanti Sanitarium, and is so pure a solution of sodic chloride that the lower water must now be almost entirely eliminated.

No. 287 is of brine from Thompson Bros.' 566-foot well at White Rock, Huron County, and is cited from Vols. III and V of the Geological Survey Michigan, as are also the remaining analyses of the section. The analysis, however, is corrected and the iron added from a statement in the report of the Commissioners to the Centennial Exposition of 1876 at Philadelphia. The specific gravity is there given as 1.155.

No. 288 is of brine from Grant & Co.'s 908-foot well, East Tawas. References as for No. 287.

No. 289 is of brine from Ayres & Co.'s 1,198-foot well at Port Austin, Huron County. References as for No. 287, and also Hunt in Geological Survey of Canada, 1866–1869, p. 220.

No. 290 is of the brine from Jenks & Co.'s well, Sand Beach. S. P. Duffield, analyst. G. W. Jenks reports that 98.7 per cent of the solids was NaCl.

No. 291 is of brine from Smith, Kelley & Dwight's 1,070-foot well at Oscoda. Same references as No. 287.

No. 291A of the Appendix is an analysis of the Berea brine where it is struck, at a depth of 2,200 feet, at Bay City, near the center of the basin, and even at this depth it has no more $CaCl_2$ than the much less deep-seated brines of Midland and Mount Clemens.

That this Berea brine is a purer solution of NaCl than the brines immediately above or below is shown not merely by comparing the Ypsilanti analyses and the analyses in general, but by such facts as when Frank Crawford's well at Caseville, which had been drawing from the Berea at 1,760 feet, was deepened to 2,270 feet it became necessary to clean the pans twice as often.

WATERS FROM BEDS BELOW THE BEREA GRIT.

When wells pass through the Berea and go through the Devonian black shales they usually encounter no water until near the bottom of the Devonian. It would be interesting, if possible, to sort out those wells which draw merely from the limestone of the Traverse (Hamilton), those which tap the upper Helderberg or Corniferous, a very well-marked horizon, and those which go deeper into the lower Helderberg and Salina; but this does not seem practicable at present, for in the southern part of the State the Traverse formation is less than 100 feet thick, and there has been little attempt, so far as I have record, to isolate the various brines. I suspect, however, that such determination might lead to important economic results, as in some of them rare elements, like K, Br, and Sr, may be richly contained. At the outcrop of

the lower Devonian limestones are the various sulphur springs mentioned by Peale and widely distributed in Monroe and Wayne counties (Erie, Shawnee, Wyandotte). For the northern part of the State the Harbor Springs' analysis (No. 53) may show what kind of water is taken into the rock. We have analyses showing very lightly mineralized waters from Charlevoix, Bay View, and Petoskey (Nos. 292, 293, 294). The Charlevoix waterworks well has probably not pierced through the (Marcellus?) shale at the bottom of the Traverse series, according to the record of the strata. On the other hand, the Petoskey well probably draws from the Dundee limestones. This well is located near the Chicago and West Michigan Railway station, and the surroundings are now somewhat changed. The view shows how they looked at the time of well drilling (Pl. III).

WATERS FROM DEVONIAN OR SILURIAN LIMESTONES.

Constituent.	292. Charlevoix.	293. Bay View.	294. Petoskey.	295. Frankfort.	296. Wyandotte.	297. Alpena No. 1.	298. Alpena No. 2.
$CaCO_3$	*5.27* / .056	*11.00* / .157			0.633	0.788	
$CaSO_4$		*4.00* / .057	*11.200* / .160	1.220	1.274	.429	*a* .109125
Fe_2O_3	*4.331* / *b* .074	*.50* / .007	*.20* / .003	.018	.004		
$FeCO_3$						.026	
$MgCO_3$	*.85* / .015	*4.70* / .067		.090		.899	
$MgSO_4$			*8.50* / .121	1.100	.691		
KCl				Tr.			
K_2SO_4			*.57* / .008		Tr.		
SiO_2	*.54* / .008	*.60* / .009	*.97* / .014	.017		(*c*)	
NaCl	*1.30* / .023	*4.20* / .060	*7.70* / .110	.409	.327	.975	.00464
Na_2CO_3					.434	.225	
Na_2SO_4	*2.02* / .035	*6.00* / .086		.580	.369		
N						*c* .240	
CO_2					.436	*c* 8.4	
H_2S			Tr.	*c* 44.5	*c* 20.00	*c* 35.36	19.02
Volatile at red heat		*6.00* / .086	*6.16* / .088				
Organic						.013	.791
Total solids	*12.31* / .212	*51.00* / .442	*45.88* / .629	3.433	4.191	3.899	3.060
Total hardness		15.°					
Permanent hardness		8.°					
Free ammonia		.00002	.00006				.09072
Albuminoid ammonia		.00001	.00005				.00174
Permanganate			.00020				.004102

a All sulphates together. *b* + Al_2O_3. *c* In cubic inches per gallon.

DRILLING OF PETOSKEY WELL.

Constituent.	299. Alpena No. 3.	300. Detroit (Riverside No. 1).	301. Detroit (Riverside No. 2).	302. Detroit (Riverside No. 3).	303. Ypsilanti No. 1.	304. Ypsilanti No. 2.	305. Ypsilanti No. 3.
Al_2O_3				0.230			
$CaCO_3$		0.281	0.191	2.556	0.6322	0.98181	0.99712
$CaCl_2$			.728	14.743		2.45765	2.87328
$CaSO_4$	3.1314	1.968	2.756	30.702	3.0802	3.01121	2.98794
$FeCO_3$			.002		Sl. tr.	Tr.	.02856
$MgCO_3$			.004	.193			
$MgCl_2$	1.3417	.445	1.882		.9911	2.19596	2.63344
$MgBr_2$					.0810	.188	
$MgSO_4$		.759		18.549	1.1659	1.774	1.94260
KCl				.003			
KBr							.26764
K_2SO_4					.2330	.6058	
NaCl	4.1835	.554	5.320	58.460	14.241	26.97644	36.94436
Na_2CO_3	.0283		.048				
NaS	.4812				.2087	.1445	
SiO_2		Tr.	.003	.000	.0240	.3398	.43910
Total	9.1677	3.997	10.941	a 132.442	20.6362	38.6788	49.11404
H_2S	.1267	b 19.02	b 14.77	6.946	b 21.0786	b 32.216	b 35.84

a Sum including H_2S. b In cubic inches per gallon.

No. 292 is of water from the Charlevoix waterworks well No. 2. Analysis obtained through H. P. Parmelee. Depth, 400 feet.

No. 293 is of water from the Bay View well. Depth, 498½ feet. Flow, 200 barrels an hour. Water likely to be roily. F. S. Kedzie, analyst, August 20, 1895. Well completed in July, 1895.

No. 294 is of water from the Petoskey well, 555 feet deep. Analyst, R. C. Kedzie. The two wells (analyses Nos. 293 and 294) are close together, but, as will be noticed on comparing their records, No. 294 has passed through and is drawing its water beneath a bed of shale, probably the base of the Traverse or the Hamilton, in which the Bay View well stopped. The Petoskey is apparently, therefore, a water from the Dundee (upper Helderberg), with the characteristic presence of H_2S, while the Bay View water is in the Hamilton.

No. 295 is of water from Butler's well at Frankfort. R. C. Kedzie, analyst. See Geological Survey Michigan, Vol. V, Part II, page 59, also plate. The temperature of 58° F., compared with the well record and statement that the main flow is at 1,400 feet, indicates that this water also is from the top of the Dundee limestone, with which its sulphated and sulphureted character is in entire accord.

No. 296, Wyandotte white sulphur springs, is of a similar water from the other end of the State. Analyst, Courtis. Cf. Peale, Bulletin U. S. Geological Survey No. 32, page 150. Generally the CO_2 is computed as bicarbonate.

No. 297, Alpena No. 1 (?), 1,164 feet deep, with chief flow at 600+ feet (?). Analyst, S. P. Duffield. Given by Peale as in grains per

United States gallon, but really per imperial gallon. The records of the first and second wells put down at Alpena seem to have been confused somewhat. See later paper; also Peale, Bulletin U. S. Geological Survey No. 32, pages 145, 147, Geological Survey of Michigan, Vol. III, Part I, page 39, and Vol. V, Part II, page 46. The temperature given by Peale, 52° F., nearly agreeing with my own observations, indicates a water about 500 feet nearer the surface than at Frankfort (900 feet), and Rominger says it is an "upper sulphur water," contaminated with a little salt from lower down. With this description both Nos. 297 and and 298 agree, and I found, by qualitative test at the well in 1897, markedly sulphated and sulphureted waters, with extremely little chlorine. The waters were then flowing naturally and not pumped, and this might give the upper water greater purity.

No. 298 is Vaughan's partial sanitary analysis of water from Alpena spring, so called because it is customary to speak of flowing wells as springs. The analysis doubtless refers to one of these wells. At any rate, in its strength in sulphates and extremely low Cl, it agrees with my qualitative tests of the wells. Brownish in color, with amoebæ, diatoms, algae, zoöglœa, several varieties of germs, and amorphous matter.

No. 299 is of water from Alpena well No. 3. Analyst, W. F. Edwards, of the Michigan University School of Pharmacy. Analysis probably made in 1892.

J. J. Mason & Co. report drilling wells 625 feet deep for the Northern Extract Company—water struck at 400 feet—which flow 450 gallons a minute and eat out the casing in about six years. These waters are merely "alkaline," whereas rock salt was struck at 1,200 feet in the Sanitarium well in 1893.

We next introduce a series of analyses of waters from wells bored in or near the Riverside bath house, corner West Fort street and South Clarke avenue, Detroit. There are said to be two wells, one more salt than the other. No. 302 is said to be of water from the two wells mixed; this can not refer to Nos. 300 and 301, but probably to No. 301 and another well put down later and still deeper. The temperature of 50° F. indicates no great depth for the wells from which samples Nos. 300 and 301 were taken, and they are not strong. No. 300 is like No. 297.

No. 300, Riverside magnetic mineral springs, Springwell's Fort, No. 1, is taken from Peale, Bulletin U. S. Geological Survey No. 32, pages 146–7, and is much like No. 296.

No. 301 is taken from Peale, Bulletin U. S. Geological Survey No. 32, pages 146–7, and is much like No. 296.

No. 302, Clark's Riverside bath house, Detroit. Depth of wells unknown. Analyst, S. P. Duffield. November 3, 1889. Cited from a pamphlet, where the analysis is given both in grains per imperial gallon and in parts per liter, the former figures being 700 times the latter. I give the latter figures multiplied by 10.

No. 303, Ypsilanti mineral springs. Depth 550 feet. Analyst, A. B. Prescott. Water drawn by his assistant March 31, 1883. Tempera-

ture, 58° F. (14.5° C.). Specific gravity at 15° C., 1.0163. Reaction alkaline. Total H_2S in volume at 58° F., 91.233 cubic centimeters. The analysis, dated May 5, 1883, is given in grains per United States gallon, not imperial gallon, as the same figures are given by Peale (p. 150), and grams per liter, the former figures being 58.37 times the latter. I give the latter figures, but, taking the specific gravity into account, the figures should be diminished by dividing by 1.063 in order to reduce to grams per kilogram, or parts per thousand. As has been noticed in connection with the Big Rapids analysis, Professor Prescott allowed for the specific gravity in stating the result in grains per gallon from parts per thousand, and has apparently done so here. But it is sometimes neglected, and I do not know how Shepherd, the analyst of No. 304, worked. I have preferred, therefore, to leave the Ypsilanti analyses as stated rather than to introduce a small and dubious correction.

This analysis (No. 303) is probably from the Cornwall mineral well or the original well (see fig. 1).

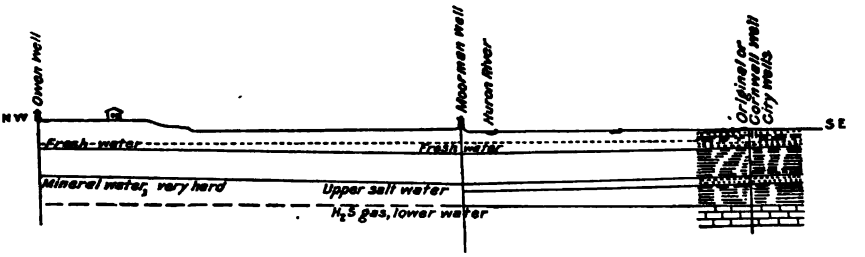


FIG. 1.—Section showing the relations of the deep wells at Ypsilanti to each other, to the wells of the city water supply, and to the several water-bearing strata.

The following is Prescott's statement of constituent acids and bases:

Total solids determined in grains	1205.6905
Hydrosulphuric acid, total in volume at 58.1° F. (14.5° C.)	91.2330
Total solids by evaporation	20.5800
Constituent bases and acids:	Grams per liter.
1. Potassa	0.1260
2. Soda	7.7120
3. Lithia	Tr.
4. Magnesia	0.8190
5. Lime	1.4865
6. Strontia	Tr.
7. Baryta	Slight tr.
8. Iron (ferrous oxide)	Slight tr.
9. Carbonic anhydride	0.3435
10. Sulphuric anhydride	2.6950
11. Hydrosulphuric acid	0.1321
12. Chlorine	9.3828
13. Bromine	0.0530
14. Fluorine	Slight tr.
15. Boric anhydride	Tr.
16. Phosphoric anhydride	Slight tr.
17. Silicic anhydride	0.0240
	22.7739
Deduction of hydrosulphuric acid and of oxygen displaced in the bromide, chlorides, and sulphide in excess over addition of sulphur in the sulphide and of water in the bicarbonate	2.1377
Total salts determined	20.6362
Total bases and acids determined	22.7739

No. 304, Ypsilanti Mineral Bath Company, Moorman mineral well. (See fig. 1.) Analyst, James H. Shepherd. Water drawn September 5, 1884. Temperature of water, 14.2° C. (57.5° F.); of air, 26.3° C. (79.3° F.). Specific gravity, 1.0280. Reaction, alkaline. The results cited are said to be in grams per liter, and are also stated in grains per imperial gallon, the latter figures being 70 times greater than those given (by which I have detected one or two misprints in the analysis as published in the pamphlet of the company; in Peale's paper also, op. cit., it should read 124.42 $MgSO_4$), and accordingly, though grams per liter are stated, parts per thousand may be meant, the imperial gallon being taken as 10 pounds. At the time this sample was taken the well was cased to 550 feet, to shut off all higher waters, and practically this is pure Dundee limestone water.

No. 305, water from same well as No. 304. Analyst, De Forest Ross, September 13, 1897. Temperature of water, 16.5° C. (?). Reaction, alkaline. Specific gravity, 1.0358. The pamphlet statement is in grains per imperial gallon. Before this analysis was made the casing was pulled back to 185 feet, so as to admit the upper stronger water of the Berea grit which is more predominant in No. 286A.

No. 306, T. C. Owen's well Atlantis, on the hill near the normal school at Ypsilanti. (See fig. 1.) Analysts, J. H. Shepherd and W. F. Pett, 1884. Peale, op. cit., page 150.

It will be noticed that No. 305 is the strongest water of the four, and that the addition of the Berea water has increased mainly the NaCl, while the sulphates have not increased in the same proportion. The relations of the three wells are shown in fig. 1.

The remaining analyses are for many reasons difficult to group. In the first place, the specific gravity is so great that parts per thousand—i. e., grams per kilogram—and grams per liter are by no means equivalent expressions. Yet chemists accustomed to analyzing waters whose specific gravity is practically unity, speak of grains per imperial gallon, when grains per unit of 70,000 grains or 10 pounds is meant. Others, like A. B. Prescott, are careful to apply the volume correction. Then, again, the specific gravity of a brine varies, at different temperatures, to a measurable, though trifling, extent (cf. analysis No. 323). Thus the reduction of the analyses to strictly comparable units is not easy. Again, one can not be sure in such analyses as are issued in advertising pamphlets whether care has been taken in proof reading, or even whether they have not been altered. A number of minor errors seem thus to have crept into Peale's list. Often the kind of gallon is not specified, and Peale's rule—to assume the United States gallon unless otherwise stated—is not safe. In fact, when most figures for different constituents are multiples of 7 the imperial gallon is probably used. Finally, as will be easily seen, the analyses vary considerably, and imperfections of analysis, though they may be considerable, are unimportant beside the larger ones due to variation, from time to time,

in the quality of the water itself. A most important factor in this connection is the character and depth of the casing, as is seen in the Ypsilanti wells just described (analyses Nos. 304 and 305). The same thing is seen in the Alma analyses (Nos. 327 to 329), in all of which cases the withdrawal of the casing admitted a different water. We do not know the condition of the casing in many instances, and, moreover, casing supposed to shut off an upper water does not always succeed in effectually doing so. How far the great variations, for example at Mount Clemens, are due to the casings remains to be proved. Then, again, variations have been found which seem to be connected with the rate of pumping. There are very few waters on the list below that are not composite—made up of waters from various levels, and, as they come from beds of varying porosity as well as varying head, a well pumped nearly to its capacity will draw more largely from the more porous beds than when it is more gently pumped. In fact, a very porous bed with low head might, under heavy pumping, yield a large proportion of the water, which would yield none in the normal flow. Such are some of the considerations which we must especially keep in mind in studying the analyses from No. 232 on. There is still another consideration which is forced upon us by the first analysis to be described.

No. 307 is supposed to be of water from the well of the Port Huron Mineral Bath Company. I am informed by Mr. W. L. Jenks, who is now interested in the well, that illuminating gas comes at 400 feet and this mineral water at about 800 feet. Compare, in Geological Survey of Michigan, Vol. V, the water at 772 feet in the Junction well, Pl. LIV. I have included this analysis rather against the wishes of Prof. A. B. Prescott, the analyist, for he does not consider it a natural water. The element which has evidently been tampered with is the bromine, which is so out of harmony with the proportions of other constituents that the discrepancy is apparent at once. Professor Prescott had the Ypsilanti mineral water drawn by his own assistant, and in that water the Br was barely a twentieth part of what it is in this analysis. The potash and iodine may also have been altered in No. 307. But I have thought it best to include the analysis—first, to show how recognizable an altered analysis is likely to be to a student of natural ones. The analysis was recognized as not natural by Professor Prescott and myself quite independently. Again, I think the real mineral water was used as a base, and in some respects the analysis is quite comparable with and an interesting link to the other Dundee limestone water analyses. The sample gave Professor Prescott a specific gravity, at 15.05° C, of 1.070, and the oxides and acids were K_2O 3.537, Na_2O 37.502, MgO 3.116, CaO 4.203, SO_3 2.312, Cl 49.408, Br 5.380, I 0.319, CO_2 0.035, SiO_2 0.010, H_2S 0.649.

It must be recognized that we are dealing with a group of waters which are unquestionably of high healing value and economically of great importance, in which there is lively competition, and where there

is a temptation for an owner to add to his well, before analysis, elements considered desirable, just as the famous Apollinaris water is said to have a little salt continually added to it. It is legitimate if there is no deception about it and if the water is kept true to its quality. The above statement may apply also to No. 310, though reported to me as coming from a well 340 feet deep. The CO_2 is certainly added, and the analysis could be nearly reproduced by diluting No. 311 with pure water one-hundred fold. I do not say that this is not an excellent table water. Strong brines must also be diluted to be drinkable, and so the St. Clair mineral water, analyzed by Professor Prescott in December, 1894, and the analysis published by the owner, was a dilution of a very strongly saline water, artificially charged with carbon dioxide, and did not represent a natural water. Most waters are artifically charged for the market.

No. 308 is of water from a well 1,400 feet deep at Benton Harbor (see Geological Survey of Michigan, Vol. V, Part II, Pl. VII). The water is known as Benton Harbor Excelsior mineral water. Prof. John H. Long, of Northwestern University, analyst. The H_2S is cubic inches per gallon at 70° F. Specific gravity of water at 70° F., 1.1058; allowed for in the reduction.

No. 309 is of water from Coldwater, sent by C. B. Randall. Professor Prescott, analyst, 1893. Compare also Geological Survey of Michigan, Vol. V, Part II, Pl. X. The bases and acids determined were as follows:

Specific gravity, at 20° C., 1.159.

	Parts per thousand.
Aluminum oxide	0.1910
Ferrous oxide	0.0249
Ferric oxide	0.0649
Manganese	Tr.
Magnesium oxide	5.2517
Calcium oxide	11.5650
Sodium oxide	82.9500
Chlorine	121.1360
Bromine	1.3040
Sulphur of sulphides	0.0012
Sulphuric anhydride	0.5650
Silicon dioxide	0.0109
Estimation of Br as described in an article by Prescott and Dunn, Jour. Anal. Chem., 3 .375 (1889)	223.0646

No. 310 is of Salutaris water, bottled and put on the market. Analyst, C. F. Chandler. Reduced from grains per United States gallon to grains per liter or kilogram. Chandler's No. 2779, June 10, 1890. This water is said to be from a well 340 feet deep, and cased down to rock. Compare above under No. 276; see also Geological Survey of Michigan, Vol. V, Part II, Pl. LXII. It is barely possible that by an unexpected fold or fault the Berea grit comes in here, for the water resembles very much that of Wales (No. 122) and Birmingham (No. 285).

No. 311 is of water from the St. Clair mineral springs. Cited by Peale, op. cit., page 149; no analyst is given. The analysis is not complete, and I have doubts as to whether it is in grains per United States or imperial gallon, and also as to the specific weight.

No. 312 is of water from the St. Clair spring, Oakland House well. Depth, 1,250 feet, cased 1,000 feet. Statement published in pamphlet is in grains per United States imperial gallon (really imperial gallon). Analyst, S. P. Duffield. "I think you would find more salt if you went deeper." "Your water shows a large proportion of calcic chloride." This analysis is remarkable for the largest proportional amount of earth chlorides, and yet only traces of bromides, etc. It would be interesting to know how much potash the water contains. (Compare No. 313.)

No. 313 is of Somerville spring mineral water, St. Clair, Michigan. Statement in published pamphlet in grains per imperial gallon (as the figures are multiples of 7). Analyst, S. P. Duffield. This well is very close to that from which sample No. 312 was taken, and yet the waters are markedly different; the analyses were made by the same chemist. Do the potash and bromide belong to an upper flow which is cased out of No. 312? In other cases also the KCl and the $CaCl_2$ are inversely proportional.

No. 314 is of water from the Mount Clemens original well, which has also at times been known as the Avery and the Soolbad. Analyst, H. F. Meier; cited in grains per gallon without specific weight, by Peale, op. cit., page 148. This water is the least mineralized of all the Mount Clemens waters analyzed, having as much or more NaCl, but being deficient in earthy chlorides, elsewhere so marked a feature of the waters. As the Mount Clemens resort, like most Michigan resorts of this class, started in an abandoned salt industry, this may represent more nearly the original brine, the casing being afterwards withdrawn to let in brine stronger in other constituents.

No. 315 is of water from the same well as No. 314—the Avery. Analyst, S. P. Duffield. As given by Peale this is in grains per United States gallon, and the $CaSO_4$ is stated as 100.56. In pamphlets I find the $CaSO_4$ 100.335 and the gallon stated as the imperial, the same figures, which are mostly multiples of 7, being used. This is the analysis of Mount Clemens water most often cited in other reports for comparison. The presence of nitrogen is interesting. Perhaps some of the rare gases recently discovered which have masqueraded behind N are also present.

No. 316 is of water from the same well as Nos. 314 and 315—the Soolbad. Analyst, S. P. Duffield, 1884. Only a partial analysis. Cited by Peale, Bulletin U. S. Geological Survey No. 32, page 148.

No. 317 is of water from the Clementine well, 1,060 feet deep, at Mount Clemens, B. B. Coursin, proprietor. Cf. Geological Survey of Michigan, Vol. V, Part II, Pl. XLII. Fenton Hotel. Analyst, Theo.

Tonnelé, McKeesport, Pennsylvania, June 14, 1893. Specific gravity 1.1313. Given on advertising card as in grains per United States gallon; specific gravity allowed for, the units for gas not given. Total solids by evaporation, at 20.5° C., 10,786.3 grains per gallon. By summation, including S 10,874.526 hydrosulphate and hydrosulphite of sodium lumped together, but not the clay and sulphide of iron, as insoluble matter. The sulphide of iron and free S indicate decomposition of the H_2S and precipitation on the long journey to Pennsylvania.

No. 318 is of water from the Mount Clemens Medea well. Depth 1,244 feet. Second well put down. See Geological Survey of Michigan, Vol. V, Part II, page 71. Analyst, S. P. Duffield, 1884. Cited by Peale, Bulletin U. S. Geological Survey No. 32, page 148, as in grains per United States gallon. This analysis is so similar to No. 319 as to appear like an incomplete version of the same; but the latter is given in grains per imperial gallon.

No. 319 is of water from the same well as No. 318. Analyst, S. P. Duffield, cited from pamphlet in grains per imperial gallon. In NaCl, $MgCl_2$, and in total solids this checks well with the Clementine analysis, No. 317; but No. 319 has $CaCl_2$ where No. 317 has the same amount approximately divided between potassic and calcic chloride.

No. 320 is of the water of the Mount Clemens Sanitarium Company, Limited. This is from the most recent well, 1,000 feet deep, with, it is believed, only 70 feet casing. Analyst, John E. Clark. Water taken July, 1896. Analysis dated August 5, 1896. Gas in cubic inches; other constituents in grains per imperial gallon. ' I have not been able to find by inquiry whether or not the specific gravity was taken into account, but I have assumed for the reduction that the imperial gallon was taken as 10 pounds. In this sample and in No. 319 CO_2 was present, but was not estimated, and the iron sulphide precipitate is included in the summation.

No. 321 is of water from the well of the Windsor Salt Works, Windsor, Ontario (directly opposite Detroit). Analyst, F. E. Englehart. Specific gravity 1.1817. I have taken this analysis, in default of any analysis of water on the Michigan side of the river, to show the nature of the lower salt brine.

The foregoing analyses show clearly the nature of the waters from a geological point of view. Passing through the impervious cap of black shale, at first comparatively weak water strongly charged with gas, especially H_2S, is struck (analyses Nos. 296, 300, 301, and 303 to 307). Penetrating deeper we come to a set of strata saturated with bitterns or mother liquors (cf. Nos. 283 and 284 with Nos. 318 and 319) deposited from the sea which was left after the great beds of rock salt, which have been and are now actively exploited through still deeper wells (analyses Nos. 320 and 321), had been laid down. Organic matter, as already mentioned, may have decomposed $CaSO_4$ and produced the H_2S.

The records of various wells, as given by Mr. Wright in Vol. V of the

reports of the geological survey of Michigan, contain a mass of data as to the specific gravity of the brines at the various depths, illustrative of these points.

No. 322 is of water from the Canfield & Wheeler well at Manistee; Geological Survey of Michigan, Vol. V, Part II, Pl. XXXI. A. B. Prescott, analyst. Analyzed between 1883 and 1890. Specific gravity at 60° F., 1.20054.

No. 323 is of water from the same well as No. 322, and by the same analyst; 1893. Evidently the brine had deteriorated in purity. Specific gravity at 16° C., 1.26; at 25° C., 1.255. The analysis was only partial, as follows:

Cl	184.477
Br	9.730
CaO	65.352
MgO	24.280
Fe	Tr.
SO_3	Sl. tr.
K	Tr.
Li	Tr.

A provisional estimate of the potassium was obtained (weighing potassic platinic chloride) giving 0.0169 per cent of K_2O. An estimate of the lithium weighed as sulphate gave duplicates for 0.0111 LiO_2, which "is surely far too high."

The estimate of the bromine was made by the indirect method described in Journal of Analytical Chemistry, Vol. III, page 375, 1889, but with a solution of silver nitrate of known strength for precipitation and estimating the excess of this solution used, so that the consumption of silver nitrate in precipitating can be held as a control for the weight of metallic silver obtained through reduction of a known amount of silver chloride bromide.

No. 324 is of brine from Sand Beach mineral well. Depth, 1,920 feet. See Geological Survey of Michigan, Vol. V, Part II, pages 80–83. R. C. Kedzie, analyst, August, 1890. Original figures are in grains per imperial gallon of 10 pounds. This and the two following analyses have an interesting history. The well whose record is given, loc. cit., was originally a salt well. When Dr. Kedzie's analysis showed the astounding and unsuspected proportions of K and Br given, Mr. George W. Jenks had the sample sent to S. P. Duffield for verification. The analysis returned, No. 325, shows an even stronger water, and, curiously enough, all the constituents increased in exactly the same proportion. Finally, a sample sent in 1896 to Hetherington & Rasher, an English firm of commercial chemists, with a view to testing before exploiting such remarkable richness, gave analysis No. 325, in which the Br and K have dropped to more usual proportions. Some comments may be made later on this whole subject. Suffice it to say now, that a considerable sample of the original water still exists at the Agricultural College, and there is every reason to believe that the

original analysis is a correct one of the original water at 1,860 feet. The sample analyzed in 1896 was mixed with a deeper water, for the well was then deeper.

No. 325 is of brine from Sand Beach. S. P. Duffield, analyst. Reference as above. Specific gravity at 60° F., 1.180. Statement given in grams per liter (really per kilogram). H_2S is 0.2271 gram or 10.745 cubic inches. Total solids directly estimated per liter, 311.6 grams.

No. 326 is of brine from Sand Beach, taken in 1896. Analysts, Hetherington & Rasher, England. Specific gravity, 1.187. Probably in this analysis the imperial gallon is really a volume, and not as in the two previous analyses 10 pounds; in such a case the total solids would agree closely. The reduction is, however, made by dividing by 70.

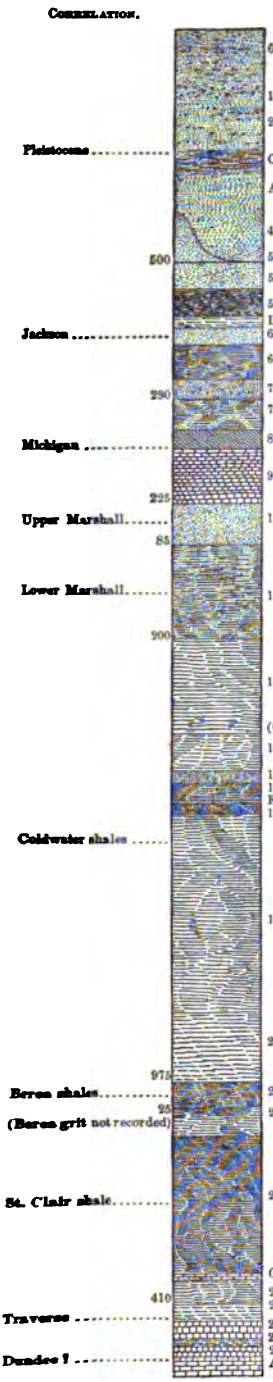
The next group of analyses are all from the same well—that of the Alma Sanitarium, Dr. J. H. Lancashire, president. The well record is illustrated in fig. 2, which, being of a deep well in the center of the basin, illustrates also the general relations of the strata for most of the other wells mentioned. The Berea grit, however, was not reported in this well; this is quite strange, as the formation is well developed at Bay City. These wells do not give off H_2S perceptibly, but a small amount of illuminating gas is discharged which the analysis does not mention. The effect of pulling back the casing so as to let in the Marshall waters seems to increase the bromine and decrease the total solid constituents. The relative increase of salt and diminution of chlorides of lime and magnesia agree in indicating that thereby a more purely salty brine like No. 281 is admitted. A similar experience was had at Ypsilanti. In other words, the Alma water is a mixture of the upper bitterns of Mount Clemens with a brominiferous Marshall water. The analyses are stated in grains per United States gallon, and I have not been able to obtain the original figures nor the specific gravity, but they should be reduced to parts per thousand, for comparison, by dividing by about 70; this implies a specific gravity of about 1.2, which must be nearly correct.

No. 327 is dated August 17, 1894. Analysts, C. F. Chandler and C. E. Pellew, of Columbia University. See Geological Survey of Michigan, Vol. V, Part II, page 46.

No. 328 is dated May 24, 1894. Same analysts and references as No. 327. The casing had been pulled back for the above analyses, I am informed.

No. 329 is dated January 15, 1890. The well struck this water in March, 1889. This I understand to be purely the bottom water. Another account of the casing is as follows:

This well was cased with 8-inch casing 500 feet, then a 5⅛-inch casing 615 feet. At 1,053 feet the hole was reduced to admit a 4¼-inch casing, which was eventually carried down to the 1,500-foot level. From this point there is no casing and we are using a pump that extends down 1,500 feet.



Well begun July, 1888; reached 2,500 feet Feb., 1889; finished June, 1889.

FIG. 2.—Geological column at the Alma Sanitarium.

Constituent.	306. Ypsilanti (Atlantis well).	307. Port Huron.	308. Benton Harbor (Excelsior well).	309. Coldwater.	310. St. Clair (Salutaris water).	311. St. Clair mineral spring.	312. St. Clair spring.
Al_2O_3	.....	.....	*0.035* .005	*a* 0.643	.....	.....	*840.00* 12.00
$CaCO_3$	0.827	.....	Tr.	.....	.....	*0.15*	Tr.
$CaCl_2$	3.000	5.118	*1,378.24* 21.350	*1,535.786* 22.717	*b 5.1337* bi. .0879	*2,457.49*	*7,383.2* 105.46
$CaSO_4$	.666	3.930	*85.449* 1.324	*13.901* .205	.....	*140.19*	*144.2* 2.06
$FeCl_2OH$	.....	.....	.....	*11.279* .167	.....	.....	.....
$FeCl_2$	.....	.....	.....	*3.672* .054	.....	.....	.....
LiCl	*d* Tr.	.....	Tr.	.....	.....	.....	.....
Barium	Tr.	.....	.....	.....	.....	.....	.....
$MgCO_3$	.....	.....	.....	.....	*c 3.8814* bi. .0665	*1.10*	Tr.
$MgCl_2$	1.911	1.012	*605.90* 9.386	*791.42* 11.70	.....	*398.38*	*1,012.2* 144.6
$MgBr_2$	.193	12.374	*46.72* .725	*101.193* 1.497	.....	Tr.	.....
$MgSO_4$	1.320	.....	.....	.....	.....	.....	.....
Fluorides	Tr.	.....	.....	.....	.....	.....	.....
Phosphates	Tr.	.....	.....	.....	.....	.....	.....
KCl	.....	5.511	Tr.	.....	*1.6979* .0293	.....	.....
K_2SO_4	.527	.080	.....	.....	Tr.	.....	.....
Silicates	.015	.....	.....	.....	.....	.....	.....
SiO_2	.....	.010	*.233* .004	*d* .0109	*.5717* .0098	*29.41*	*406.00* 5.800
NaCl	34.457	70.871	*6,821.13* 105.680	*10,911.25* 161.39	*81.3344* 1.388	*e 9.56501*	*8,120* 116.00
NaI	.....	.377	.....	.....	.....	MgI tr.	MgI tr.
NaS	.....	.....	.....	*.1346* .002	.....	.....	.....
$NaHCO_3$	.....	.....	.....	.....	*4.8754* bi. .08135	.....	.....
Organic matter	Tr.	.....	.....	.....	Tr. NH_3	.....	.....
Total by addition	42.916	99.283	8,938.002	.....	.....	*12.57173*	17,904.6
Total by evaporation	.....	.....	138.474	*13,413.831* 198.3601	*97.4943* 1.671	.....	255.78
H_2S	*f* 15.527	.649	*f* 27.8	Tr.	.....	*f* 16.43	*f* 25.597
CO_2	.....	.....	.....	.....	*465.325*	.....	.....
Sp. wt	.....	.....	1.1058	.....	.....	.....	.....

a Aluminum sulphates.
b $CaH_2(CO_3)_2$.
c $MgH_2(CO_3)_2$.
d And borates.
e + KCl.
f Cubic inches.

Constituent.	313. St. Clair (Somerville spring).	314. Mount Clemens (original well).	315. Mount Clemens (Avery).	316. Mount Clemens (Soolbad).	317. Mount Clemens (Clementine).	318. Mount Clemens (Media).	319. Mount Clemens (Media).
Al_2O_3			*29.47* *.421*	*11.21*	*2.920* *.044*	*29.00*	*42.07* *.601*
NH_4Cl		Tr.		Tr.		Tr.	
$CaCO_3$		*3.98*	*0.98* *.014*	Tr.		*91.00*	*0.91* *.013*
$CaCl_2$	*2,303.78* 40.054	*172.41*	*934.5* 13.35		*2,827.606* 42.820		*4,128.53* 58.979
$CaSO_4$	*87.78* 1.254	*35.20*	*100.335* 1.433	*44.00*	*69.970* 11.060	*14.80*	*143.43* 2.049
Fe_2O_3	*30.100* .430			Tr.		*8.500*	
$FeCO_3$			*.560* .080				*8.54* .122
$FeH_2(CO_3)_2$					*1.924* .029		
$FeCl_2$							
FeS		Tr.			*a433.536* 6.5626		
LiCl				Tr.			
$MgCO_3$		Tr.	*0.70* .01	Tr.		*0.70*	*0.07* .001
$MgCl_2$	*242.90* 3.470	*129.60*	*648.48* 9.264		*1,228.002* 18.596		*1,656.2* 23.66
$MgBr_2$	*68.60* .980		*6.37* .091	Tr.		Br. *8.50*	*8.54* .122
MgI_2		*b 0.32*	*0.07* .001	*b 0.05*		*b .07*	*.07* .001
KCl	*1,680.00* 24.00	Tr.		Tr.	*1,067.889* 116.020		
SiO_2	*119.00* 1.700	*c 8.97*	*27.60* .394			*28.00*	*28.09* .401
NaCl	*8,983.94* 128.342	*8,637.44*	*11,900.00* 170.00	*d 11,181.00*	*5,684.255* 86.080	*11,741.00* (e)	*5,957.35* 85.105
Na_2SO_4	*f 11.9* .170	*77.25*			*g 1.960* .0		
Sr					Tr.		
S					Tr.		
Organic		Tr.					
Total solids	*14,028.00* 200.4	*9,065.17* 155.00	*13,654.105* 195.062	*11,236.26* 192.00	*10,374.526* 164.678	*11,921.07* 170.301	*11,973.80* 171.054
H_2S		*h* 27.52	*h* 40.00	*h* 33.00	*h* 9.910	*h* 40.00	*h* 38.00
CO_2		Tr.	*h* 5.85		*h* 3.457		

a Insoluble and not included in summation.
b Iodine.
c +Al_2O_3.
d +Ca+Mg.
e Na+Ca+Mg.
f Hydrous.
g Hydrosulphate and hydrosulphite of sodium.
h Cubic inches.

Constituent.	320. Mount Clemens Sanitarium.	321. Windsor, Ontario.	322. Manistee No. 1.	323. Manistee No. 2.	324. Sand Beach No. 1.	325. Sand Beach No. 2.	326. Sand Beach No. 3.
$CaCl_2$	*10,166.356* 145.234	.3643	$CaMgCl_2$ 3.449	129.54	56.89	62.6636	*2,875.00* 41.07
$CaSO_4$	*75.909* 1.0844	5.443	4.395	.....	.90	.9936	*40.6* .58
$FeH_2(CO_3)_2$	*2.149* .031	.....	.....	.....	.....	.....	.....
$FeCO_3$	*122.998* *a* 1.757	.....	.....	.....	Tr.	.....	.....
LiCl	.....	.....	.....	Li_2O. 111	.....	.....	.....
$MgCl_2$	*843.493* 12.050	1.6652	.....	46.11	4.85	5.3542	*1,571.00* 22.44
$MgBr_2$	Tr.	.....	.....	11.19	22.500	24.84	*58.5* .836
MgI_2	Tr.	.....	.....	.....	.....	.....	.....
KCl	*2.945* .042	.....	.....	.....	34.22	37.7788	*215.00* 3.07
K_2O	.....	.....	.....	.169	.....	.....	.....
SiO_2	*2.112* .030	.....	.....	.....	.....	.7303	.....
NaCl	*8,709.906* 124.4187	227.0157	(*b*)	111.14	162.64	179.2391	*14,230.00* 203.29
Loss	.....	.....	.....	.....	.....	.....	*1,079.00* 15.414
Total solids	*19,947.277*	.....	.....	.....	*19.740*	*21.812*	*20.0691*
Grams per liter	284.9611	234.4872	262.00	297.98	282.00	311.60	288.13
H_2S	*c* 38.00	.....	.....	.....	*c* 10.5	*c* 10.745	.....

a FeS. *b* Rest of solids are mainly NaCl. *c* In cubic inches.

Constituent.	327. Alma No. 1.	328. Alma No. 2.	329. Alma No. 3.	Constituent.	327. Alma No. 1.	328. Alma No. 2.	329. Alma No. 3.
Al_2O_3	*5.0325*	*3.905*	*4.0823*	SiO_2	*1.4883*	.8324	*4.6654*
NH_4Cl	*41.9133*	*43.0859*	.....	NaCl	*8,963.7825*	*9,581.3243*	*9,539.5974*
$CaCl_2$	*6,514.2006*	*6,304.2741*	*7,324.0548*	NaBr	*84.9091*	*80.8238*	*154,026.00*
$FeCl_2$	*22.4089*	*15.4101*	*23.0911*	NaI	Tr.	Tr.	Tr.
LiCl	Tr.	Tr.	Tr.	Sodium phosphate	Tr.	Tr.	Tr.
$MgCl_2$	*2,465.4775*	*2,256.9909*	*2,215.8903*				
KCl	*125.5798*	*63.7845*	*100.6261*	Total	*18,240.7291*	*18,408.6813*	*19,241.0949*
K_2SO_4	*15.8466*	*58.1949*	*18.6849*				

RÉSUMÉ.

In spite of the difficulties, upon which I have enlarged perhaps too much, I am able to make some generalizations of interest and I trust of practical value.

If we take any one stratum yielding water, we find that the deeper it is the more strongly mineralized it is. At the margin the salts are more often carbonates and sulphates, and are replaced below by chlorides, and the earthy chlorides and bromides, etc., appear to be richer in the deeper or central parts. But the rate of mineralization is far from the same in different beds. The freshest horizons for a given depth appear to be the Dundee and the Marshall. The former appears to be characteristically sulphureted, far more so than any other horizon. The latter is the chief horizon for potable water, and is capable of supplying a large part of the State, but must be shielded in many cases from overlying waters. Above the Marshall the waters are likely to be mineralized even if quite shallow, and generally strong in sulphates, with or without salt. Below the Marshall is the Berea grit, which is somewhat saline even in shallow wells, yields excellent brine in the deeper wells, illuminating gas and oil rather than H_2S, and is marked by the predominance of sodium and the relative freedom from earthy chlorides. Has this any connection with its isolation in a shale series away from any limestone? Below the Dundee the predominance of these earthy chlorides is characteristic, and also probably the concentration of K and some of the rarer elements from the great salt depositing process, the results of which we find still farther down.

So far as the rarer elements and less sought for compounds are concerned, it must be said, however, that analytical methods are not yet satisfactory for brines. The Midland Chemical Company is a large manufacturer of bromine, practically dominating the industry, and is said to have improved methods of analysis. But these are commercial considerations. I have had complaints that efforts had been made in vain to get from the East Tawas brines the bromine that was said to be there. Again, the presence of celestite associated with sulphur at Scofield and other points in the Helderberg series, suggest that Sr must be a constant constituent of the sulphureted waters. But its presence, even in traces, is rarely noted in the analyses. Doubtless, if especially looked for, it would be found more widely diffused. On the other hand, I have been assured by a competent chemist that the Michigan brines differ from those of Ohio and Pennsylvania in the absence of iodine and lithium. Ammonic chloride, reported from Alma, is probably widespread and generally overlooked.

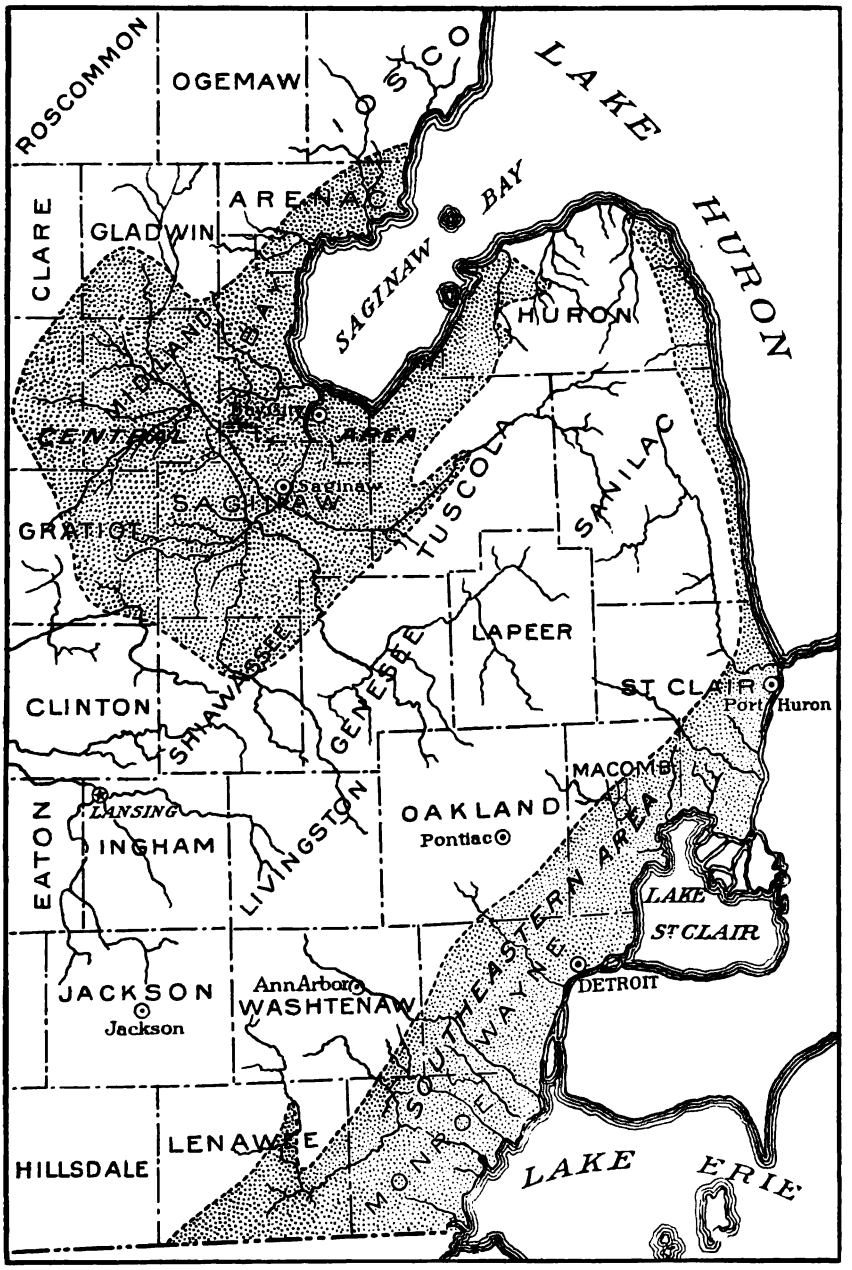
From the Dundee and the limestone series below are a number of interesting brines which we are not yet able to differentiate. The first analysis of the Sand Beach brine was, I believe, correct, and the brominiferous pocket was either exhausted or diluted with a lower water,

for even the English analysis shows a notable amount of K and Br. The general criticism may be made, on the exploitation of the undoubtedly valuable medicinal bitterns of Michigan, that too little attention and study has been given to the precise effects of the various components in particular classes of diseases. Although both a sulphureted water and a saline water have medicinal values, they are not exactly the same. Yet the usual custom is to let them flow together and to continue boring until the salinometer shows considerable strength, so that "the bathers may feel the buoyancy and feel that they are getting their money's worth," and it is desired that the analysis may show as strong a water as a neighboring establishment, or a similarity to some famous water. No attempt to separate the various waters and use them according to the circumstances of the case seems to have been made, further than to have one well for drinking and another for bathing. And yet anywhere along the Detroit and St. Clair rivers it would be easy enough to have, even from one well, a sulphureted water, a calcium chloride water, and a strong salt water, and perhaps other varieties, to be used as each case required.

I have been told that hygienic living and drinking plenty of water are essentially the most important curative agents, and next to them is salt. So far, however, as particular mineral and gaseous ingredients are really of importance, the plan above suggested would certainly be a step in advance. Again, in view of the evidence of gradual changes in analysis, perhaps from deterioriation of casing, it would be well to keep weekly records of salinometer strength and temperature and also of the quantity of water pumped, which would quickly indicate any leak in the casing, and if any notable difference was thus detected it might be well to analyze the water again.

In studying the sanitary analyses of potable waters I am brought to the conclusion that, so far as typhoid and kindred diseases are concerned, direct microscopic investigation and bacteriological study are more important than consideration of chemical constituents as indicators of sewage contamination. It is easy to see that chlorine in particular is no guide, unless one knows accurately the normal percentage for uncontaminated water under the same geological conditions. Prof. Delos Fall, of the State board of health, is pursuing researches along this line. In many cases even an abnormally low percentage of mineral matter or salt is suspicious, as indicating dilution with rain and other surface water. This is especially true of abnormally soft waters.

I have given the dates of the analyses, because the State board of health has shown that the prevalence of typhoid fever increases with the lowering of the water in the wells, the curves of their diagram showing the prevalence of typhoid from month to month and the parallel lines the height of water in the wells. The lowest water (231 inches below ground on the average) and the greatest number of cases of typhoid occur in October, the highest water (197 inches below ground) and the fewest cases of typhoid in the spring.



MAP SHOWING AREAS OF HEAVILY MINERALIZED SHALLOW WATERS

Not only does ammonia occur in peaty waters, which are not necessarily dangerous, though likely to be malarial, but in the Alma well, at a depth of 2,860 feet we find it playing the same rôle as magnesium or calcium. Hence it is not a reliable indication of contamination. It does not, however, by any means follow that a chemical examination of ordinary waters is valueless. With due regard to all conditions, such analyses may furnish valuable indication as to sewage contamination, and it is one of the objects of this paper to enable the chemist to study and judge what the normal analysis should be. But germ diseases are not the only ailments of man, and extremely hard waters, like those around Mount Pleasant, are by no means wholesome simply because there is no possible surface contamination. The relation between the percentage of various mineral constituents and certain chronic diseases, and the uric acid diathesis has not, to my knowledge, been carefully studied. The map (Pl. IV) shows by shaded areas those parts of the State where the waters commonly drunk are most likely to be highly charged with mineral matter, and it would be interesting to see if these areas correspond in any significant way to disease distribution. Of course in these shaded areas there are many surface wells of nonmineral waters. Yet the waters of many wells are strongly cathartic or otherwise unpleasant to those unused to them, as strangers coming temporarily to help in harvest and threshing soon discover. It seems natural to suppose that a water which will favorably affect some sick people will unfavorably affect others, and that some waters may be permanently too strong for some constitutions, while other systems which may be at first decidedly unsettled by them in time become perfectly accustomed to them. Throughout the central or shaded area, in chronic diseases like rheumatism and constipation it might be worth while to experiment with pure filtered rain water (flavored if necessary with a little salt or lithium carbonate) as a beverage.

In regard to brine for salt making, rock salt and very pure brines occur in the Salina, north of a line from Trenton to Muskegon. Next ranks the brine of the Berea, and then that of the Marshall.

Just above the Salina the rocks seem to be saturated with bitterns. That would seem to be a most hopeful field to develop for potash salts. September 29, 1899, newspapers report that explorations, particularly for potash, will begin in October. Some of the Coal-Measure waters seem also to run relatively high in potash. At considerable depths both this horizon and the Marshall seem to possess bromides in valuable quantities.

APPENDIX.

The Appendix contains some analyses which were received too late for insertion in their proper places without entirely renumbering the analyses. References to these later analyses have, however, been

	5A. Detroit.	6A. Detroit.	7A. Detroit.	7B. Lake Michigan, Milwaukee.	7C. Lake Michigan, Chicago.
Number of bacteria per cu. cm	140	9 95 15 110 18 80	80 to 800	.....	520.
Loss on ignition, organic matter	0.0420	0.0412	0.0320	0.080	.0024
Nitrates	.....	.....	.00013	0.	.....
Albuminoid ammonia	.00008	.00007	.00008	.0000005	.00008
Free ammonia	.00007	.00006	.00006	.0000075	1.00000
NaCl	.0042	.0043	.0045	.0092	.....
Organic suspended matter	.0007	.....	.....	.....	.0180
Inorganic suspended matter	.0137	.....	.....	.....	.....
Total solids	.1240	.1100	.1144	.2000	.13

Constituent.	35A. Boardman River.	35B. Boardman River.	35C. Asylum brook.	35D. Spring near Asylum.	36A. Brook near Agricultural College.
$CaCO_3$	CaO 0.0588	$CaCO_3$ 0.0744	0.122	0.135	.....
$CaSO_4$	0.0	.0455	.007	.008	.....
Fe_2O_3	Much.	.....	.....	.....	.....
$FeCO_3$	.....	.0001	.003	.002	.....
$MgCO_3$	MgO .0147	.0400	.015	.060	.....
SiO_2	.....	.0078	.005	.003	.....
NaCl	.0077	.0167	.002	.001	.....
Loss on ignition	.060	.....	.09	.064	.1083
Total solids at 212° F	.190	.1964	.2440	.268	.2695
Albuminoid ammonia	.00002	.....	.0005	.002	.....
Free ammonia	.00007	.....	.001	.0015	.....
Temporary hardness	9.°	.....	.....	.....	2.5°
Permanent hardness	6.°	.....	.....	.....	6.°
O from permanganate by boiling	.02	.....	.....	.....	.....

Constituent.	43A. Saginaw River.	43B. Saginaw River.	43C. Saginaw River.	43D. Saginaw River.
CaO	*5.95* .085	*4.83* .069	*6.80* .077	*5.60* .080
$Fe_2O_3 + Al_2O_3$	*3.15* .045	*3.43* .049	*4.73* .067	*4.20* .060
MgO	*.63* .009	*2.02* .029	*.50* .007	*1.50* .021
SiO_2	*.515* .0045	*.35* .005	*1.19* .017	*.35* .005
NaCl	*2.76* .039	*2.76* .039	*4.84* .069	*5.07* .072
SO_3	*2.60* .037	*2.39* .034	*1.04* .015	*2.48* .036
Organic residue	*5.25* .075	*4.20* .060	*7.35* .105	*9.10* .130
Total residue	*22.75* .325	*24.15* .345	*23.80* .340	*28.35* .405

Constituent.	58A. "Pagoda," Mount Clemens.	Constituent.	58A. "Pagoda," Mount Clemens.
Al_2O_3	Tr.	NaCl	*1.959* .0280
$CaCO_3$	*10.273* .1468	Na_2SO_4	*1.234* .0176
$CaSO_4$	*.359* .0051	P_2O_5	Sl. tr.
$FeCO_3$	*.067* .0009	Organic	Sl. tr.
$MgCO_3$	*5.473* .0782	Sum	*20.195* .2885
K_2SO_4	*.306* .0044	CO_2	19.2 cu.in.
SiO_2	*.524* .0075		

	172A. Lansing.	172B. Lansing.		172A. Lansing.	172B. Lansing.
Result of inoculation			Potassium permanganate reduced	0.002	0.004
Number of bacteria in 72 hours		235	Cl as NaCl	.00825	.01485
Nitrites	0	0	Organic residue	.017	.100
Nitrates	0	0	Inorganic residue	.041	.232
Albuminoid ammonia	0.000021	0.000019	Total residue	.058	.332
Free ammonia	.000013	.000021	Hardness	4.°	4.8°

Constituent.	No. 286A. Ypsilanti.	No. 291A. Bay City.	Constituent.	No. 286A. Ypsilanti.	No. 291A. Bay City.
Al_2O_3	*10.5* .15	.18	NaCl	*9,632.99* 137.61	162.86
$CaCO_3$	*194.71* 2.78		NaBr	*12.60* .18	*b* .17
$CaCl_2$		67.85	NaI	*5.60* .08	
$CaSO_4$	*161.84* 2.312	.04	H_2S	*144.10* 2.06	
Fe_2O_3	*a 17.50* .25	.31	P_2O_5	Tr.	
$MgCl_2$	*255.76* 3.65	10.67	Total solids by evaporation	*10,476.60* 149.67	262.1
KCl	*42.70* .61		Total solids by calculation	*10,478.50* 149.69	262.08
SiO_2					

a Carbonate. *b* MgBr.

No. 286A is a recent analysis of water from the Ypsilanti Sanitarium. Analyst, Prof. John E. Clark, of Detroit. Specific gravity, 1.038; reaction slightly alkaline; analysis in grains per imperial gallon. Note that the H_2S appears to be included in the total solids by calculation.

No. 291A is of the brine encountered in the Bay City deep well at 2,200 feet, which rose to the surface, notwithstanding a specific gravity of 1,2223. Analyst, Prof. F. S. Kedzie.

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1895.

Sixteenth Annual Report of the United States Geological Survey, 1894-95, Part II, Papers of an economic character, 1895; octavo, 598 pp.

Contains a paper on the public lands and their water supply, by F. H. Newell, illustrated by a large map showing the relative extent and location of the vacant public lands; also a report on the water resources of a portion of the Great Plains, by Robert Hay.

A geological reconnoissance of northwestern Wyoming, by George H. Eldridge, 1894; octavo, 72 pp. Bulletin No. 119 of the United States Geological Survey; price, 10 cents.

Contains a description of the geologic structure of portions of the Big Horn Range and Big Horn Basin, especially with reference to the coal fields, and remarks upon the water supply and agricultural possibilities.

Report of progress of the division of hydrography for the calendar years 1893 and 1894, by F. H. Newell, 1895; octavo, 176 pp. Bulletin No. 131 of the United States Geological Survey; price, 15 cents.

Contains results of stream measurements at various points, mainly within the arid region, and records of wells in a number of counties in western Nebraska, western Kansas, and eastern Colorado.

1896.

Seventeenth Annual Report of the United States Geological Survey, 1895-96, Part II, Economic geology and hydrography, 1896; octavo, 864 pp.

Contains papers on "The underground water of the Arkansas Valley in eastern Colorado," by G. K. Gilbert; "The water resources of Illinois," by Frank Leverett, and "Preliminary report on the artesian waters of a portion of the Dakotas," by N. H. Darton.

Artesian-well prospects in the Atlantic Coastal Plain region, by N. H. Darton, 1896; octavo, 250 pp., 19 plates. Bulletin No. 138 of the United States Geological Survey; price, 20 cents.

Gives a description of the geologic conditions of the coastal region from Long Island, N. Y., to Georgia, and contains data relating to many of the deep wells.

Report of progress of the division of hydrography for the calendar year 1895, by F. H. Newell, hydrographer in charge, 1896; octavo, 356 pp. Bulletin No. 140 of the United States Geological Survey; price, 25 cents.

Contains a description of the instruments and methods employed in measuring streams and the results of hydrographic investigations in various parts of the United States.

1897.

Eighteenth Annual Report of the United States Geological Survey, 1896-97, Part IV, Hydrography, 1897; octavo, 756 pp.

Contains a "Report of progress of stream measurements for the calendar year 1896," by Arthur P. Davis; "The water resources of Indiana and Ohio," by Frank Leverett; "New developments in well boring and irrigation in South Dakota," by N. H. Darton, and "Reservoirs for irrigation," by J. D. Schuyler.

1898.

Nineteenth Annual Report of the United States Geological Survey, 1897-98, Part IV, Hydrography, 1899; octavo, 814 pp.

Contains a "Report of progress of stream measurements for the calendar year 1898," by F. H. Newell and others; "The rock waters of Ohio," by Edward Orton, and "A preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian," by N. H. Darton.

WATER-SUPPLY AND IRRIGATION PAPERS, 1896-1899.

This series of papers is designed to present in pamphlet form the results of stream measurements and of special investigations. A list of these, with other information, is given on the outside (or fourth) page of this cover.

Survey bulletins can be obtained only by prepayment of cost, as noted above. Postage stamps, checks, and drafts can not be accepted. Money should be transmitted by postal money order or express order, made payable to the Director of the United States Geological Survey. Correspondence relating to the publications of the Survey should be addressed to **The Director, United States Geological Survey, Washington, D. C.**

WATER-SUPPLY AND IRRIGATION PAPERS.

1. Pumping water for irrigation, by Herbert M. Wilson, 1896.
2. Irrigation near Phœnix, Arizona, by Arthur P. Davis, 1897.
3. Sewage irrigation, by George W. Rafter, 1897.
4. A reconnoissance in southeastern Washington, by Israel C. Russell, 1897.
5. Irrigation practice on the Great Plains, by E. B. Cowgill, 1897.
6. Underground waters of southwestern Kansas, by Erasmus Haworth, 1897.
7. Seepage waters of northern Utah, by Samuel Fortier, 1897.
8. Windmills for irrigation, by E. C. Murphy, 1897.
9. Irrigation near Greeley, Colorado, by David Boyd, 1897.
10. Irrigation in Mesilla Valley, New Mexico, by F. C. Barker, 1898.
11. River heights for 1896, by Arthur P. Davis, 1897.
12. Water resources of southeastern Nebraska, by Nelson Horatio Darton, 1898.
13. Irrigation systems in Texas, by William Ferguson Hutson, 1898.
14. New tests of pumps and water lifts used in irrigation, by O. P. Hood, 1898.
15. Operations at river stations, 1897, Part I, 1898.
16. Operations at river stations, 1897, Part II, 1898.
17. Irrigation near Bakersfield, California, by C. E. Grunsky, 1898.
18. Irrigation near Fresno, California, by C. E. Grunsky, 1898.
19. Irrigation near Merced, California, by C. E. Grunsky, 1899.
20. Experiments with windmills, by Thomas O. Perry, 1899.
21. Wells of northern Indiana, by Frank Leverett, 1899.
22. Sewage irrigation, Part II, by George W. Rafter, 1899.
23. Water-right problems in the Bighorn Mountains, by Elwood Mead, 1899.
24. Water resources of the State of New York, Part I, by George W. Rafter, 1899.
25. Water resources of the State of New York, Part II, by George W. Rafter, 1899.
26. Wells of southern Indiana (continuation of No. 21), by Frank Leverett, 1899.
27. Operations at river stations, 1898, Part I, 1899.
28. Operations at river stations, 1898, Part II, 1899.
29. Wells and windmills in Nebraska, by Erwin Hinckley Barbour, 1899.
30. Water resources of the Lower Peninsula of Michigan, by Alfred C. Lane, 1899.
31. Lower Michigan mineral waters, by Alfred C. Lane, 1899.

In addition to the above, there are in various stages of preparation other papers relating to the measurement of streams, the storage of water, the amount available from underground sources, the efficiency of windmills, the cost of pumping, and other details relating to the methods of utilizing the water resources of the country. Provision has been made for printing these by the following clause in the sundry civil act making appropriations for the year 1896–97:

Provided, That hereafter the reports of the Geological Survey in relation to the gauging of streams and to the methods of utilizing the water resources may be printed in octavo form, not to exceed 100 pages in length and 5,000 copies in number; 1,000 copies of which shall be for the official use of the Geological Survey, 1,500 copies shall be delivered to the Senate, and 2,500 copies shall be delivered to the House of Representatives, for distribution. [Approved, June 11, 1896; Stat. L., vol. 29, p. 453.]

The maximum number of copies available for the use of the Geological Survey is 1,000. This number falls far short of the demand, so that it is impossible to supply all requests. Attempts are made to send these pamphlets to persons who have rendered assistance in their preparation through replies to schedules or who have furnished data. Requests specifying a certain paper and stating a reason for asking for it are granted whenever practicable, but it is impossible to comply with general requests, such as to have all of the series sent indiscriminately.

Application for these papers should be made either to Members of Congress or to

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C.

DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 32

WATER RESOURCES OF PUERTO RICO.—WILSON

WASHINGTON
GOVERNMENT PRINTING OFFICE
1899

IRRIGATION REPORTS.

The following list contains the titles and brief descriptions of the principal reports relating to water supply and irrigation prepared by the United States Geological Survey since 1890:

1890.

First Annual Report of the United States Irrigation Survey, 1890; octavo, 133 pp.

Printed as Part II, Irrigation, of the Tenth Annual Report of the United States Geological Survey, 1888-89. Contains a statement of the origin of the Irrigation Survey, a preliminary report on the organization and prosecution of the survey of the arid lands for purposes of irrigation, and report of work done during 1890.

1891.

Second Annual Report of the United States Irrigation Survey, 1891; octavo, 395 pp.

Published as Part II, Irrigation, of the Eleventh Annual Report of the United States Geological Survey, 1889-90. Contains a description of the hydrography of the arid region and of the engineering operations carried on by the Irrigation Survey during 1890; also the statement of the Director of the Survey to the House Committee on Irrigation, and other papers, including a bibliography of irrigation literature. Illustrated by 29 plates and 4 figures.

Third Annual Report of the United States Irrigation Survey, 1891; octavo, 576 pp.

Printed as Part II of the Twelfth Annual Report of the United States Geological Survey, 1890-91. Contains "Report upon the location and survey of reservoir sites during the fiscal year ended June 30, 1891," by A. H. Thompson; "Hydrography of the arid regions," by F. H. Newell; and "Irrigation in India," by Herbert M. Wilson. Illustrated by 93 plates and 190 figures.

Bulletins of the Eleventh Census of the United States upon irrigation, prepared by F. H. Newell; quarto.

No. 55, Irrigation in Arizona; No. 60, Irrigation in New Mexico; No. 85, Irrigation in Utah; No. 107, Irrigation in Wyoming; No. 153, Irrigation in Montana; No. 157, Irrigation in Idaho; No. 163, Irrigation in Nevada; No. 178, Irrigation in Oregon; No. 193, Artesian wells for irrigation; No. 198, Irrigation in Washington.

1892.

Irrigation of western United States, by F. H. Newell; extra census bulletin No. 23, September 9, 1892; quarto, 22 pp.

Contains tabulations showing the total number, average size, etc., of irrigated holdings, the total area and average size of irrigated farms in the subhumid regions, the percentage of number of farms irrigated, character of crops, value of irrigated lands, the average cost of irrigation, the investment and profits, together with a résumé of the water supply and a description of irrigation by artesian wells. Illustrated by colored maps showing the location and relative extent of the irrigated areas.

1893.

Thirteenth Annual Report of the United States Geological Survey, 1891-92, Part III, Irrigation, 1893; octavo, 480 pp.

Consists of three papers: "Water supply for irrigation," by F. H. Newell; "American irrigation engineering" and "Engineering results of the Irrigation Survey," by Herbert M. Wilson; and "Construction of topographic maps and selection and survey of reservoir sites," by A. H. Thompson. Illustrated by 77 plates and 119 figures.

A geological reconnoissance in central Washington, by Israel Cook Russell, 1893; octavo, 108 pp., 15 plates. Bulletin No. 108 of the United States Geological Survey; price, 15 cents.

Contains a description of the examination of the geologic structure in and adjacent to the drainage basin of Yakima River and the great plains of the Columbia to the east of this area, with special reference to the occurrence of artesian waters.

1894.

Report on agriculture by irrigation in the western part of the United States at the Eleventh Census, 1890, by F. H. Newell, 1894; quarto, 283 pp.

Consists of a general description of the condition of irrigation in the United States, the area irrigated, cost of works, their value and profits; also describes the water supply, the value of water, of artesian wells, reservoirs, and other details; then takes up each State and Territory in order, giving a general description of the condition of agriculture by irrigation, and discusses the physical conditions and local peculiarities in each county.

Fourteenth Annual Report of the United States Geological Survey, 1892-93, in two parts; Part II, Accompanying papers, 1894; octavo, 597 pp.

Contains papers on "Potable waters of the eastern United States," by W J McGee; "Natural mineral waters of the United States," by A. C. Peale; and "Results of stream measurements," by F. H. Newell. Illustrated by maps and diagrams.

(Continued on third page of cover.)

DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 32

WASHINGTON
GOVERNMENT PRINTING OFFICE
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UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

WATER RESOURCES OF PUERTO RICO

BY

HERBERT M. WILSON

WASHINGTON
GOVERNMENT PRINTING OFFICE
1899

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, July 31, 1899.

SIR: I have the honor to transmit herewith a manuscript relating to the water resources of Puerto Rico and to request that it be published as one of the series of Water-Supply and Irrigation Papers. The report is based on notes, sketches, and photographs gathered by Mr. Herbert M. Wilson during a brief journey made through the island of Puerto Rico in January, 1899. The object of this trip was primarily to study the topographic characteristics and the water resources of the island, but incidentally numerous memoranda relative to the soil, agricultural products, and forests were obtained.

Mr. Wilson landed at the capital city of San Juan, whence a short trip was made by rail via Rio Piedras to Carolina, whence saddle animals were taken still farther eastward to Canovanas and southward up the river of that name to its head waters, in the Sierra de Luquilla. After returning to San Juan he proceeded by ambulance over the military road, which crosses the island diagonally toward the southwest, via Caguas, Cayey, Aibonito, Coamo, and Juana Diaz, to Ponce, traveling by slow stages and making the distance of 80 miles in four days.

At Ponce Mr. Wilson and his party were furnished with pack and saddle animals and civilian packers and set out the next day via Adjuntas and Lares, San Sebastian, and Añasco to Mayaguez, on the west coast. Thence the return journey to Ponce was made on horseback via Hormigueros and San German to Yauco, where rail was taken for Ponce.

Thus the trip included the country from the mountain tops near the eastern end of the island to near the southeast coast above Guayama and to the south coast at Ponce, a return to near the northwest coast at Lares, and a circuit of the southwestern coast from Mayaguez to Ponce. The party crossed or visited the head waters of all the more important streams, saw nearly the entire country from the vantage points of the high summits, and visited nearly all of the larger cities except those at the eastern extremity of the island.

This route led into the highest mountains at the eastern end of the island, within view of El Yunque, the highest peak; also into the Sierra de Cayey and the Cordillera Central, occupying the main length of the island, and, finally, into the low coral sugar loaves near Lares, and the limestone and volcanic foothills of the Tetas de Cerro Gordo and Las Sillas de Calderon, in the southwestern corner of the island. The data thus obtained concerning the water resources of this newly acquired portion of the United States are believed to be of sufficient importance to warrant early publication in this series of papers.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

WATER RESOURCES OF PUERTO RICO.

By HERBERT M. WILSON.

TOPOGRAPHIC RELIEF.

Puerto Rico, as shown on the map (Pl. I), is situated between latitudes 17° 54′ and 18° 30′ north and longitudes 65° 13′ and 67° 15′ west, thus lying well within the Torrid Zone. It is the easternmost as well as the southernmost of the Greater Antilles, though still farther to the east are the lesser of the West Indian islands belonging to the Windward Group. The shores are washed on the north by the waters of the Atlantic Ocean, on the south and east by those of the Caribbean Sea, and on the west by Mona Passage, which separates the island from Haiti. According to the best information obtainable from measurement of existing maps, the area of Puerto Rico, exclusive of the dependent islands—chief among which are Mona on the west and Viequas and Culebra on the east—is 3,670 square miles. Its area is thus one-fourth, or 1,200 miles, less than that of the State of Connecticut, and is nearly three times as great as the area of Long Island. Its average width is 35 miles, or twice the width of Long Island, while its average length is 105 miles, or about the same as that of Long Island. Fourth of the Greater Antilles in size, it is roughly rectangular in form, its major axis lying almost exactly east and west.

The essential topographic characteristic of Puerto Rico is its exceedingly mountainous and highly eroded aspect, in spite of which none of its summits attain great altitude. The island is also notable for the abruptness with which the foothills of the mountain slopes plunge into the ocean, leaving practically no marginal coast plain, and for the variety in topographic form, resulting from great differences of erosive action at either extremity of the island and from changes in geologic structure. Extending irregularly through the entire length of the island from the extreme northeastern point, at Cabeza de San Juan, to the extreme western points, near Rincon and Cabo Rojo, is a series of connected mountain ranges forming the main divide between the drainage of the north and south coasts. At the eastern end of

this island the most commanding range, the Sierra de Luquilla, terminates near its eastern extremity in the highest peak on the island, El Yunque, the elevation of which is given by Spanish authorities as 1,520 meters, or approximately 4,940 feet. This appears to be an error, since, according to an aneroid reading by Mr. A. Hansard, its height is about 3,250 feet, while the maps of the United States War Department and charts of the United States Hydrographic Office and of the United States Coast and Geodetic Survey give its altitude as between 3,610 and 3,790 feet. Which of these elevations is most nearly correct it is at present difficult to ascertain. A north-south cross

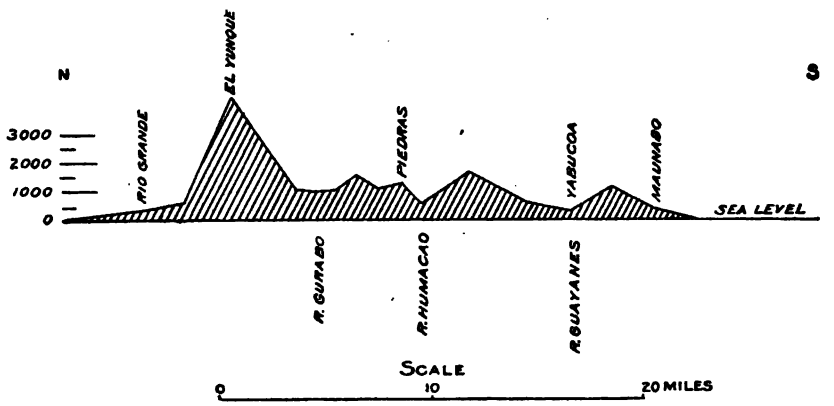

FIG. 1.—Section north and south through El Yunque.

section through El Yunque (fig. 1) gives some idea of the abruptness of the fall to the north, and is in striking contrast to the cross sections taken elsewhere on the island (figs. 2 and 3), which show the steepest slopes to the south.

A southern spur of the Luquillas connects this mountain range with the northeastern spur of the Sierra de Cayey in a low divide but 5 miles from the coast, near Humacao; thence the Sierra de Cayey extends westward to Aibonito Pass with comparatively uniform elevations between 2,200 feet in the lowest divides and 3,200 feet on the highest summits, none of which are especially pronounced. This portion of the main range of mountains skirts the eastern and southern coasts very closely, so that the greater portion of the drainage of the eastern third of the island is to the north, the southern and eastern coasts receiving the drainage from a narrow belt of country but 5 to 10 miles in width. The length of the drainage to the north, measured in an air line, is from 25 to 30 miles.

At Aibonito the military road from San Juan to Ponce passes through the lowest divide in the central range of mountains, the elevation of this being approximately 1,840 feet above sea level. As a result of the closeness with which these mountains skirt the eastern and southern coasts, they suddenly fall off in a distance of but 2 to 3 miles hori-

zontally from altitudes of 2,500 to 3,000 feet to the back coast border, at elevations of 200 to 300 feet. The abruptness of the escarpment to the south and east can thus be realized, and is illustrated by a north-south cross section (fig. 2) constructed through Guayama and San Juan. This cross section also shows that the fall to the north, while not so great, is still quite abrupt, reaching the elevated basin about

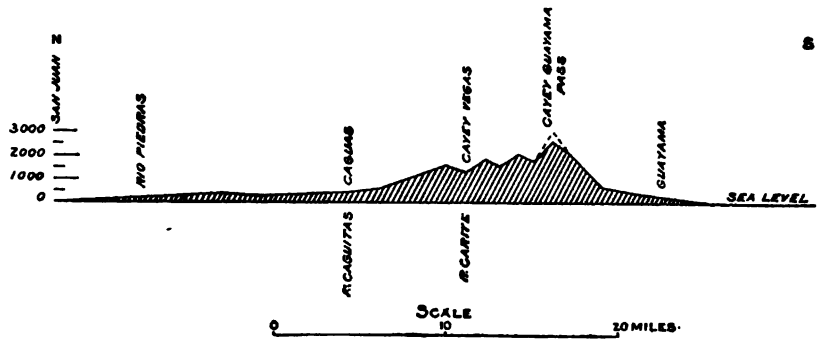

FIG. 2.—Section north and south through San Juan.

Cayey at an altitude of 1,200 feet, and is thence more gradual through the rolling country drained by the Rios Loiza and Guayanabo, in the neighborhood of Caguas, Aguas Buenas, and Comeiro.

To the west of Aibonito the main dividing range rises sharply in a broader and more strongly maintained sierra, which has here the name Cordillera Central. The passes through the Cordillera attain altitudes of 2,500 to 2,800 feet, but upon it there are no marked peaks, the highest summit scarcely reaching 3,300 feet in altitude. The Cordillera Central is interrupted to the north of Ponce in a pass 2,320 feet in altitude, leading to Adjuntas, at the head waters of the Rios Portu-

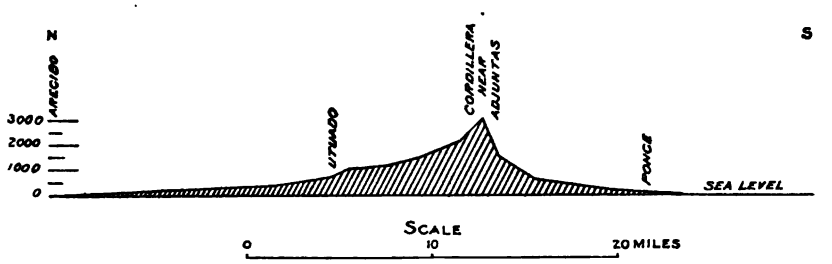

FIG. 3.—Section north and south through Ponce.

gues and Arecibo. A cross section of Puerto Rico from Ponce to Arecibo (fig. 3) does not differ materially from that between Guayama and San Juan, the chief points of difference being that the slopes to the south do not fall away quite so abruptly as farther east, while to the north the slope is decidedly more gradual than in the neighborhood of Caguas.

West of Adjuntas the sierra rises abruptly to El Guilarte, altitude 3,608 feet, which is the second mountain on the island in height. Here the character of the main dividing mountain range is abruptly changed. A number of rugged spurs branch northwestward toward Lares and Las Marias, westward toward Hormigueros, and southwestward toward San German. These spurs have not the continuity of the main mountain range from which they spring, but are broken up into a number of irregular ridges and peaks of extremely rugged aspect.

The series of controlling mountain ranges as sketched above are of the same geologic time and origin; all are of mixed volcanic and sedimentary origin, consisting chiefly of hornblende-andesites, gneiss, and tuff, embedded in which, but found at altitudes generally below 2,000 feet, is a compact blue limestone of Cretaceous time.

Abutting against the foothills of these commanding sierras, and forming secondary topographic features of striking importance, are a number of varied forms found at different portions of the island and owing their shape and mode of weathering to their geologic origin. On the north coast, between Arecibo, San Juan, and Fajardo, the main summits fall away rather abruptly to elevations of between 1,000 and 1,500 feet; they then continue as radial spurs, sloping gently to the northward and interrupted by numerous undulations, culminating often in peaks of considerable altitude and prominence.

These are separated by the principal rivers draining the interior, which flow generally to the north, but are deeply indented in the surface of the country. Thus within 5 or 6 miles to the north of the main summits the river bottoms are at altitudes of about 1,000 feet, while the summits of the ridges above are at elevations of 2,000 to 2,500 feet. Again, within 5 miles of the coast, the river beds are at elevations of 50 to 100 feet above sea level, while the summits of the dividing ridges reach altitudes of 1,000 to 1,500 feet. These dividing ridges are often maintained to the ocean shore, are high, narrow, and A-shaped, and are separated one from the other by deep V-shaped valleys eroded by numerous streams flowing in every direction throughout the interior of the island.

COASTAL TOPOGRAPHY.

The topography of the coast border consists of narrow marginal plains extending here and there up the river valleys for from 3 to 5 miles. These flat coast lands are called playas, and their continuity is broken on the northeast, southeast, and northwest by spurs of the main mountain mass which plunge directly into the ocean. These encircling plains and playas are, moreover, irregularly broken by low coast hills. On the south these are all of limestone and are 200 to 400 feet in height; on the north they are a series of old coral reefs eroded into detached hills of 50 to 150 feet in height. Thus the coast topog-

raphy may be divided into three types, distinct from the central mountain mass, consisting of (1) the playas or plains; (2) coast hills and parting valleys which separate the latter from the foothill spurs of the central mountains; and (3) a highly eroded coral plateau, an intermediate topographic type beween the sierras and the coast topography, found in the northwest portion of the island between Arecibo, Lares, and Isabela. The ascent to this latter from the west in the neighborhood of Aguadilla is abrupt and the surface of the plateau is gently rolling. This is cut by the more important streams, which have eroded abrupt canyon walls 150 to 200 feet in height. To the south this is topped by a higher series of sugar-loaf shaped buttes of coral, the summit elevation of which is about 1,200 feet.

Still another topographic type, distinctive only in that it is an exaggeration of the limestone hills and parting valleys found elsewhere, is that between Mayaguez, Cabo Rojo, and Ponce, in the southwestern corner of the island. Here the sea is bordered by a low ledge of coral, capped by a heavy stratum of hard limestone. This is tilted upward

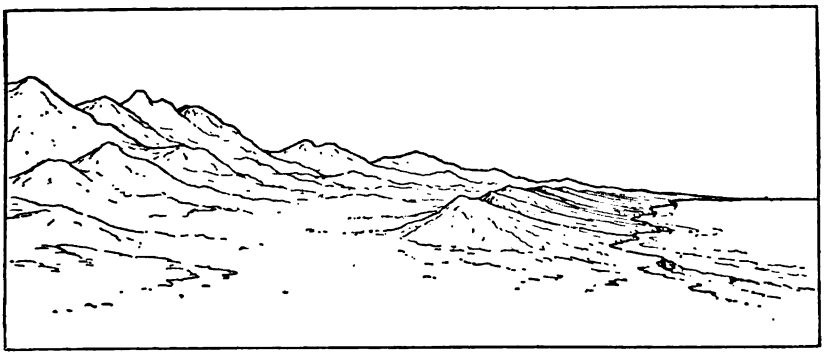

FIG. 4.—Cordillera Central, parting valley, coast limestone hills, and playa at Ponce.

so as to rise from the southwest toward the center of the island, and is separated from the main sierra by two long and fertile parting valleys.

Elsewhere on the island, and especially well developed from Ponce eastward to beyond Guayama, the low coast hills of limestone have their east-west continuity broken by the playas at the stream mouths. They are also separated from the main sierra by short, narrow parting valleys, eroded by branches of the streams which drain the main summits (fig. 4). Some of these hills terminate abruptly at the sea in bluffs 100 feet in height, while the parting valleys which border them on the north have elevations of 100 to 200 feet, their summits reaching altitudes of 500 to 1,000 feet.

PHYSIOGRAPHY AND SCENERY.

In order that the topographic forms of the island may be more clearly comprehended, the following detailed description is given of some of the more striking surface characteristics along the route traveled.

The country traversed—by railway eastward from San Juan as far as Carolina, and thence by military road to Rio Grande—is typical of the larger playas reaching from the sea margin to the back coast border. This is a comparatively flat alluvial plain (see Pl. II, *A*) about the mouth of the Rio Loiza and its branches. It has been built up largely through the aid of mangrove growth, which has encroached upon the sea and retained the alluvium brought down by the streams. Between Rio Piedras and Carolina this alluvial plain is 5 miles in width from the seashore. Its greatest width, near the mouth of the river opposite the town of Loiza, is 9 miles. In the total air-line distance of 20 miles from near San Juan to beyond Rio Grande this plain is cut by three large lagoons, and the area of this magnificent stretch of agricultural land is about 100 square miles. The whole is well cultivated in a rich forage grass, called "Guinea grass," and in sugar cane.

To the south of the edge of this playa the hills rise rapidly in broken spurs, which radiate from the summit of the Sierra de Luquilla. This playa land is, moreover, not an unbroken plain. It is comparatively level, however, rising from a few feet to about 60 to 75 feet above sea level. The apparently dead level of this playa is interrupted by occa sional low, bluff-topped hills of coral rock (see Pl. II, *B*), which have not been entirely eroded away.

A journey southward from Canovanas, up the river of that name to the summit of the Sierra de Luquilla, brings one immediately into the roughest of the highly eroded and rugged mountains which are so characteristic of the island. Cart roads extend up this river, as well as up all the other more level streams, until the diminished width of the gorge through which it flows and the roughness of the country cause them to be superseded by trails. The river flows over a rough, rocky bed and between steep slopes (see Pl. II, *C*), which are thickly covered with natural and cultivated vegetation. The cart road and the trail ford the river fifteen or twenty times in a distance of about 6 miles, due to the sharp curves of the stream between the confining mountain slopes. At the end of that distance, at an elevation of about 250 feet, the gorge has become so narrowed that the trail leaves it and climbs abruptly, in 2 or 3 miles, to an altitude of 1,350 feet. In all directions branch trails lead up the steepest slopes to the habitations of the peasants, who are everywhere engaged in the cultivation of the various crops which thrive best in each particular locality. (See Pl. II, *D*.)

The military road from San Juan to Caguas passes through a hilly depression, between the western terminus of the Sierra de Luquilla and the northern spurs of the Cordillera Central. The divide between the drainage basins of the Rios Loiza and Bayamon is crossed at an altitude of but 375 feet. At Caguas a broad mountain valley on the head waters of the various branches of the Rio Loiza is entered at an altitude of 230 feet. The slopes in every direction are not abrupt;

A, CAROLINA PLAIN, WITH EL YUNQUE IN DISTANCE

B, PLAYA AT MOUTH OF RIO LOIZA.

C, RIO CANOVANAS.

D, FOOTHILLS OF SIERRA DE LUQUILLA, SHOWING FIELD AND COCOANUT TREES

A, VIEW WEST FROM CAYEY DIVIDE.

B, RIO JACAGUAS NEAR JUANA DIAZ.

their altitudes are not great, and all are well cultivated. The road southward to Cayey remains in the general depression at the head waters of the Rios Loiza and Plata, and is surrounded on the east and south by much higher and more rugged mountains, which slope upward to the summits of the main divide. To the northeast are numerous highly eroded ridges and peaks, the northward radial spurs of the Sierra de Cayey and of the Cordillera Central. Las Cruces, the highest pass between the head waters of the Rios Loiza and Plata, is crossed at an altitude of 1,310 feet. (See Pl. III, *A*.) Immediately thereafter the road descends abruptly to the "vegas," or plain, between altitudes 1,080 and 810 feet, extending for about 6 miles to and beyond Cayey. The valley about that city is gently rolling, the country sloping away rather abruptly to the Rio Plata on the north, whence it rises rapidly to the higher summits of the northward radial spurs. To the south the summits of the main divides are nearly 2,000 feet directly over the valleys. Abrupt as are the slopes all are heavily covered with soil and vegetation.

Beyond Cayey the road climbs rapidly to the main divide between the drainage areas tributary to the north and south coast. (See Pl. IV, *A*.) This divide is crossed within 2 miles of Aibonito at an altitude of 1,860 feet. Thence there is a gradual descent of but 100 feet to the rolling tableland about Aibonito, beyond which at an equal distance is a second summit with an altitude of 1,810 feet. The summits of the main sierra, as seen from the Aibonito uplands, have everywhere the same highly eroded forms, irregularly shaped mountain ridges, long spurs, and isolated peaks, jutting out in every direction to altitudes of 500 to 1,000 feet above the rolling upland on which their bases rest at elevations of 1,700 to 2,000 feet.

Beyond the second summit at Aibonito Pass the road descends with great abruptness in but 6 miles, as measured along its meanderings, and only 2 miles in an air line, for 1,400 feet, to an altitude 420 feet. Here is some of the most magnificent mountain scenery. (See Pl. V, *A*.) The character of the topography, as well as of the flora, changes entirely as the semihumid side of the island is approached. The brilliant green here disappears from the vegetation, the damp moss and fern-covered slopes are gone, and all is covered with short, dry grass (see Pl. VI), not unlike the bunch and buffalo grass of the West, with acacias and with other arid flora. At the same time the topographic forms do not exhibit the same high degree of erosion. Though exceedingly abrupt, the mountain slopes are more uniform and less intensely cut into separate spurs and peaks. The depth of the soil is much less than on the northern slopes, and rocky ledges and bluffs occasionally protrude.

The whole of the region from San Juan to Aibonito is picturesque in the extreme, and has an exceedingly pastoral and peaceful aspect. Caguas Valley is ideally beautiful. It is almost circular, about 3 by

4 miles in dimension, and through it winds in great serpentine curves the Rios Caguitas and Turabo. The former makes a long coil about El Monte, a lone hill 300 feet in height which occupies the center of the valley. (See Pl. IV, *B*.) Among the higher summits about Aibonito the country still has the same picturesque aspect, the same pleasantly pastoral appearance, accentuated only by the immensity of the slopes. From the higher summits the Atlantic Ocean is in plain view to the north and the Caribbean Sea to the south. Every detail of topography may be seen for miles in all directions, as though one were viewing a model map.

Beyond Cayey and thence to Coamo the great mountain masses rise to such sheer heights or descend so abruptly to the bottoms of great gorges as to be imposing in the extreme. Between Coamo, Juana Diaz, and Ponce the aspect of the country is entirely dissimilar to that seen elsewhere on the route. The military road skirts the southern slopes of the Cordillera Central and remains at a fairly constant distance of 5 miles back of the coast. It crosses six of the more important rivers which drain the southern slopes (see Pl. III, *B*), yet at no place does it attain an altitude greater than 250 feet above sea level, nor at the stream crossings is it less than 100 feet above sea level.

To the north the masses of the main sierra rise abruptly in great jagged spurs, with fairly uniform slopes. In all other directions the country is a rolling plain, broken by numerous ridges and detached hills. (See Pl. VI.) These are separated by small and level parting valleys, relatively broad and all under cultivation, chiefly in sugar cane. (See Pl. X, *C*.) The entire south coast is 1 to 7 miles in width, averaging about 5 miles, and from east of Guayama to a little west of Ponce is of this same general character. The sea is bordered by coral reefs, sometimes, especially near the river mouths, by small playas, and back of these, often quite close to the coast, rising northward there is a tilted limestone table-land. This is eroded into detached hills and ridges both by the north-south primary drainage and by the east-west lateral drainage which forms the parting valleys. There is thus seen to be a large area of excellent agricultural land along the coast, but this is generally so arid as to require irrigation for the cultivation of such thirsty crops as sugar cane. Small fruits and vegetables are grown without irrigation and all the hills are covered with forage grass. The mountain slopes on this side, however, are not nearly so extensively cultivated as on the north side. In addition to the disadvantage of unfavorable soil and insufficient precipitation, comparatively little foothold is given to vegetation on their steep sides.

On the road from Ponce to Adjuntas, which ascends first the general course of the Rio Magueyes and near the summit crosses to the head waters of the Rio Portugues, one has an almost south-north cross section of the sierras, as compared with the diagonal section viewed

A, VIEW BETWEEN CAYEY AND AIBONITO SUMMIT.

B, CAGUAS VALLEY AND EL MONTE.

C, HILLS ALONG RIO ANASCO.

D, VIEW NEAR SUMMIT OF ADJUNTAS PASS.

A, SCENERY SOUTH OF AIBONITO SUMMIT.

B, BENT MANGO TREES SAN JUAN.

in traveling southwestward from Aibonito to Ponce. The topographic characteristics are identical with those seen, however, on the latter route. Four miles to the north of Ponce the elevation is but 50 feet. The way climbs for the next 3 or 4 miles through sloping foothills to an altitude of 400 feet. Thereafter, in 2 miles horizontally, the ascent to the main ridge dividing the two rivers is to an altitude of 1,720 feet. With equal abruptness the main summit (see Pl. IV, *D*) is reached about 15 miles from Ponce, at an altitude of 2,320 feet.

Adjuntas is on the northern slope and on the head waters of the Rio Arecibo. About it the topographic characteristics are in all respects similar to those observed at Aibonito. But a few miles to the southwest rises El Guilarte; to the north are seen long radial spurs of the main sierra, which are separated at Utuado by the valley of the Arecibo; northwestward another long spur extends to and beyond Lares and San Sebastian to the western sea at Aguadilla. This separates the head waters of the various rivers which empty into the northern ocean between Arecibo and Aguadilla and the drainage of the Rios Culebrina and Prieto, which flow into the western sea at Aguadilla and Añasco, respectively. The spur which extends to the southwest, and on which are El Guilarte, Las Sillas de Calderon, Tetas de Cerro Gordo, and other prominent peaks, separates the waters of the Rios Prieto and Blanco from those of the Rio Guanajibo.

It is thus seen that the neighborhood of Adjuntas is, as the name implies, the dividing point of the main sierra, which has extended with unbroken crest from its easternmost summit at El Yunque. At this point it is separated into a number of spurs of almost equal prominence, which reach the western coast with several ramifications, the most prominent of which is necessarily that containing the group of summits above named.

The various trails leading westward from Adjuntas toward Las Marias and Lares follow the head waters of the Rio Blanco or Rio Prieto for a short distance. Thence they climb to altitudes of about 2,000 feet at the summits of the divide separating the various drainage lines. These divides are high A-shaped ridges, separated by great V-shaped canyons with relatively smooth slopes 1,000 feet in depth, all well covered with vegetation. Everywhere throughout this region, on the highest summits and in the bottoms of the most profound gorges, are found the habitations of the peasantry, who gain a comfortable living from the cultivation of coffee and of fruits and vegetables.

From the summit above Lares (Pl. VII, *A*), the altitude of which is 2,000 feet and which is called La Torre, a magnificent view is had of the surrounding landscape. To the east, south, and southwest are great masses of the most rugged mountain forms. In the first direction the high and serrated northward spurs of the Cordillera Central form the horizon line. To the south one looks across the gorge of the

Rio Blanco, 1,500 feet in depth and but a mile distant, whence the eye climbs a space of but a few miles to the highest summits of El Guilarte and Las Sillas de Calderon. To the north and northwest the country slopes away to the point, apparently but a few miles distant, where the sea and sky meet in a dull gray line. The topographic aspects in this direction are entirely different from anything heretofore seen. The immediate foreground slopes away gradually to an altitude of about 1,000 feet in the neighborhood of Lares, beyond which, extending from the north through 80° toward the west, is a long line of sugar-loaf shaped coral hills (see fig. 5). These are but 250 to 350 feet in height, their summits reaching altitudes of about 1,200 feet. Some are covered with smooth green slopes and others have their surfaces broken by steep bluff ledges of coral. These "Piloncillos" or "Farallones," as the Spanish-American calls them, have the general appearance of a great group of conical-shaped Sibley

FIG. 5.—Piloncillos, or conical coral hills; Lares.

tents and in this locality go under the general name of "Pepino hills," though similar topographic features in other portions of the West Indies are called by the English "cockpits."

Between Lares and San Sebastian the country is generally similar in topographic aspects to the region north of Cayey and Caguas toward San Juan. San Sebastian is at an elevation of 270 feet. From it fall away toward the west the gorges of the various rivers which drain that slope, and these are separated by high ridges having altitudes of but 500 to 800 feet, rising, however, to altitudes of nearly 1,000 feet as they approach the ocean. North of Añasco a high and serrated ridge maintains its bulk to the very margin of the sea, into which it plunges with abrupt slopes. The same is true of the ridges which approach the ocean to the north of Aguadilla, and in less degree of those north and south of Mayaguez. At the mouths of the principal rivers in the neighborhood of Aguadilla, Añasco, and Hormigueros

BARREN HILLS NEAR JUANA DIAZ: PEASANT'S HOUSE AND ORANGE TREE IN FOREGROUND.

are extensive alluvial playas similar to those already described, and highly cultivated in sugar cane.

The country traversed by the main highway from Mayaguez via San German and Yauco to Ponce has already been generally described as differing essentially in topographic characteristics from any of the other portions of the island passed over. The road skirts the southwestern slopes of the main sierra. Between it and the sea, distant in some places as much as 8 to 10 miles, are a series of low, rolling limestone hills tilted upward toward the interior and separated by two extensive parting valleys. The erosive action which has produced the long valleys marking the junction line between the foothills which parallel the main mountains promises, according to Mr. R. T. Hill, to reduce these valleys to sea level in the near geologic future, and thus to cut off from Puerto Rico a small island including the country round about Cabo Rojo and Lajas.

From Mayaguez, through Hormigueros and San German, to Sabana Grande is a great valley, through which flows the Rio Guanajibo. It is this which separates the main summits from the rolling foothills to the south, which are hereby dignified by the collective name of Cerro Gordo. Between Sabana Grande and Yauca is a low divide connecting the Cerro Gordo with the main sierra and separating the greater valley from a similar but smaller valley, which includes the lagoon of Guanica and extends from Guayanilla and Yauco to the port of Cabo Rojo. (Pl. VIII, *A*.) Still south of the valley and separating it from the Caribbean Sea is a second well-defined ridge of low limestone and coral hills.

CLIMATOLOGY.

Situated as the island is, with a middle latitude of about 18° 15′ N., which is well within the torrid zone, it is seen to be in the same approximate latitude as the City of Mexico, the Hawaiian Islands, the Sahara Desert, and Bombay, India. Because it is the easternmost of the Great Antilles, however, its climate is so tempered by the trade winds as to render it more moist and salubrious than that of any of the regions named, with the possible exception of the Hawaiian Islands.

To the trade winds primarily, and to the influence upon them of the high mountain summits in the interior of the island, are to be ascribed the moderate temperature and the peculiar distribution of precipitation which characterize this island. Though smaller in area by 1,000 square miles than the State of Connecticut, its extremes are subject to as great difference in rainfall, both in amount and occurrence, as are the extremes of the United States. The trade winds blow with unceasing regularity throughout the year, though not with such force as to be disagreeable. Their pressure is felt as wind movement but a short distance from the northern and eastern coasts, yet

their influence is exerted throughout the island, most perceptibly to the east and north of the mountain summits which form the watershed between the Atlantic Ocean and the Caribbean Sea. Their strength and persistence is witnessed in the shape of the trees on the north or windward coast (see Pl. V, *B*), where the trees are bent southwestward or away from the prevailing winds much as those on the southern coast of California bend eastward or landward away from the prevailing Pacific winds.

Heavily moisture laden from the warm ocean, the trade winds press against the mountains, which quickly condense the moisture they bear, and heavy showers of sudden occurrence but short duration result. Southward and westward the same winds continue to cause even more abundant precipitation at the sierra summits near the center of the island. Crossing these the winds are suddenly freed and expand, and being thus given power to carry in suspension a larger amount of moisture, they let fall but little rain over the southern and western slopes.

PRECIPITATION.

The above conditions are clearly recorded in such meteorologic data as has been collected by Prof. Mark W. Harrington, of the United States Weather Bureau, from existing Spanish records. According to a bulletin issued by the Weather Bureau, records for a period of twelve years show the average annual precipitation in San Juan to be 59.5 inches. This is fairly well distributed throughout the year, the greatest monthly mean (7.62 inches) occurring in November, but that amount is closely approached during the entire rainy season from April to November, inclusive. During the remainder of the year, in the so-called dry season, the mean monthly precipitation falls to a minimum of 1.8 inches in February. The persistence of rainfall throughout the year is still further accentuated by the fact that the least precipitation recorded at San Juan in any month was 0.3 of an inch in March of one year, while the greatest was 17.1 inches in August of another year.

While these figures give an indication of the range of precipitation in the neighborhood of San Juan and near the north coast, they form no criterion for the relative amounts falling elsewhere on the island. Records of observations made by Capt. Arthur C. Hansard at Hacienda Perla, published by the Weather Bureau, indicate quite different conditions there. This place is situated on the northeast coast, only about 20 miles east of San Juan, and about 3 miles from the sea, at an elevation of 460 feet. The records show an average annual precipitation of 123.4 inches during the two years 1896 to 1898, the maximum, 136.2 inches, occurring in 1897. The distribution of rainfall was similar to that at San Juan, the minimum monthly precipitation being 2.5 inches in February and the maximum 32.9 inches in May. During this period the greatest consecutive twenty-four-hour

A, VIEW WESTWARD TOWARD LARES FROM LA TORRE SUMMIT.

B, VIEW TOWARD LARES FROM THE EAST. COCOANUTS AND BANANAS IN FOREGROUND.

rainfall was 8.4 inches in August. In this period there averaged two hundred and fifty days a year in which over one-hundredth of an inch fell. The great differences in precipitation between two places so close together is partly accounted for by the fact that Hacienda Perla lies under the northern slope of El Yunque, the highest mountain on the island, and it feels therefore more strongly the effect of the compression of the trade winds than does San Juan, which is situated on the coast, and behind which the mountains rise more gradually and at a considerably greater distance to less altitudes than those behind Hacienda Perla. As shown by the accompanying profiles (figs. 1, 2, and 3), the highest summits back of San Juan, at the headwaters of the Rios Plata and Loiza, reach altitudes of 2,700 feet in a horizontal distance of 30 miles.

Back of Hacienda Perla an altitude of over 3,700 feet is attained in less than 3 miles horizontally. Farther inland to the south and west of San Juan, under the summits of the main sierra in the neighborhood of Cayey, Aibonito, Barros, and Adjuntas, the precipitation is considerably greater than at San Juan, though not nearly so great as at Hacienda Perla. This is because these points are at a much higher elevation and are nearer the mountain crests than is the capital city, and feel more directly their effect upon the trade winds.

Apparently great as are these extremes of precipitation, they are small as compared with those between points on the south and north coasts. According to data gleaned from Spanish records, it appears that the average annual precipitation on the southern slope of Puerto Rico is but 20 inches, against 55 to 123 inches on the northern slopes. This amount, however, is most irregularly distributed. There is said to be an authentic record at Guayama, immediately south of San Juan, of thirteen months, chiefly in the year 1893, when not an inch of rainfall was recorded. The records at Cabo Rojo show one period of three years in which no rain fell.

Such great changes in precipitation, as well as in geologic formation and soil composition, result in great differences in the flora of the two coasts. Puerto Rico may be said to have a humid as well as an arid side. This is evidenced not only by the perpetual muddiness of the roads on the north slope as compared with their dry and dusty surfaces on the south, but especially by the vegetation and the regimen of the rivers.

On the north, nearer the mountain summits, the flora is always bright and verdant and of true tropical luxuriance (see Pl. IV, *A*), and the rivers carry large volumes of water. In the south, especially near the southwestern extremity of the island, the trees are dwarfed hardwoods; cacti, century plants, and acacias abound, and the vegetal as well as the topographic characteristics are similar to those of the semiarid Southwest of the United States. (See Pl. VIII, *B*.) The river beds, moreover, are almost dry and are full of rocks and bowlders.

These two salient facts, the diversity of climate and of soil composition, must be kept prominently in mind in any consideration of agricultural or water resources or of highway construction. They make it clearly evident that any generalizations on these subjects for the whole island are valueless, and, small as is the area, each particular locality must be considered by itself in discussing the development of its products. It is scarcely necessary to add that while irrigation is not practiced on the northern side of Puerto Rico, all the wealth of sugar produced on the semihumid side is dependent for its successful cultivation on water supplied by irrigation.

TEMPERATURE.

The temperature is very evenly distributed in height and range, and is in marked contrast to the variations in precipitation. It need not be discussed in detail, as it has little bearing upon problems connected with the agricultural resources, the development of irrigation, or the construction of highways. It is chiefly interesting because of its uniformity and the resulting healthfulness of the climate. The highest recorded temperature was that of 100.8° F., in the month of May, and the lowest but 56.1°, in the month of December. Rarely, indeed, has a temperature lower than 57° been recorded, and as rarely one above 97°. The average annual temperature recorded in San Juan during twelve years was 78.1°, the lowest mean monthly temperature being 74.7° in February of one year and the highest mean monthly temperature 81.1° in June of another year, a range of but 6.4° in extreme mean monthly temperatures.

At Hacienda Perla the average annual temperature is 76.9°, or but 1° lower than at San Juan. At the same place the maximum recorded, 95°, is lower by 5°, and the minimum is higher, 61°. Elsewhere in the mountains the range of temperature is about the same. On the south coast, as in the sierras, there are no authentic records, but there appears to be great uniformity of temperature everywhere on the island.

HYDROGRAPHY.

In spite of the smallness of the island, and the consequent short length of its rivers and restricted areas of their catchment basins, it is unusually well watered, because of the comparative humidity of the climate. Moreover, because of the steepness of the slopes, especially on the northern coast, and the impervious character of the clay soil which covers them, the proportion of precipitation which runs off makes these rivers of even larger volume than would otherwise be expected under corresponding conditions. Into the northern ocean flow 12 streams of considerable magnitude; toward the west coast flow 4 of relatively equal size; into the eastern sea flow 5 of less magnitude, and into the southern sea flow 17 of considerable size but comparatively small perennial volume. In addition, there are between 1,200

and 1,300 streams and branches of less volume, but yet of sufficient size to bear separate names.

Since the average width of the island is but 35 miles and its extreme length but 105 miles, while its commanding summits range in altitude from 2,800 to 3,750 feet, it is evident that the slopes are steep, the fall of the rivers great, and the velocity of their waters high. Moreover, as the main summits of the dividing mountain ranges have been shown to be one-third nearer the southern and eastern coasts than the northern and western, it is also evident that such streams as flow to the north and west are three or four times as long and drain ten to fifteen times as great areas as those flowing to the south and east. The former have average lengths of 25 to 40 miles, measured along their stream beds; the latter have lengths of but 5 to 15 miles. For these and the reasons already given the streams flowing north and west necessarily have less abrupt slopes than do those which drain eastward and southward, which plunge from an altitude of 3,000 feet to sea level within a comparatively few miles.

It is thus seen that as the island is divided climatologically into two distinct portions, it is similarly divided hydrographically, largely as a result of the same causes—the trade winds and the topographic configuration of the surface.

Of the twenty-eight larger rivers above enumerated, each has its source high among the summits of the Cordillera Central. Those flowing to the north and west are characterized by precipitate descents of 1,000 to 2,000 feet in the first 5 miles of their head waters. Thereafter they flow more leisurely and with consequent increased size to within 5 miles of the coast. There they emerge practically at sea level in long, meandering curves through the alluvial playas about their mouths. Because of the lowness of their grades near the coast and their resulting low velocity, all are of considerable width and moderate depth in the playa levels. A few miles inland, where they flow over steep, rocky beds, their channels are narrow and often confined by precipitous rocky walls, their width is of but comparatively few feet, their depth often less than a foot, and their velocities so high as to render them veritable mountain torrents (see Pl. II, *C*).

On the southern coast the larger rivers have bed widths as great as those entering the northern and western coast. Their lengths, however, are so short for the same fall that they are not characterized by the long stretches of low, meandering grade found near the coast in the playas to the north. They emerge, on the contrary, from the mountains at but 3 to 5 miles from shore line at altitudes of 200 to 400 feet, and as a result this elevation is passed with comparatively steep slopes over rocky or bowlder-strewn channels. Above these coastal stretches and within the mountains the lengths of the rivers are so short for the relatively great heights which they fall that their dimensions are little greater than those of the smallest brooks which flow from the hill summits in the Rocky Mountains.

The rivers of the north and of the west are more like the streams of humid regions in the United States, as their perennial discharge is always fairly well maintained. The larger of these rivers have at low-water stage bed widths of 150 to 200 feet, average depths of 2 to 4 feet, and minimum discharges of 250 to 1,500 second-feet. (See Pl. VIII, *C*.) In time of flood, although these rivers attain maximum discharges of 10,000 to 20,000 second-feet, these volumes are not greatly in excess of the flood discharges of the rivers of the southern slope.

The width of stream bed of the southern rivers is often as great as that of those entering the northern coast, but owing to the infrequency and small amount of the precipitation and the relatively porous character of the soil reducing the percentage of run-off, as well as to the smallness of their catchment basins, they discharge minimum volumes of but 50 to 100 second-feet. These streams resemble the rivers of our Western plains in that their beds are nearly dry the larger part of the year (see Pl. VIII, *D*), but are yet of sufficient capacity to discharge great volumes during the sudden floods to which they are subject. The beds of these rivers, even near the coast, are bowlder strewn and are from 100 to 300 feet in width. The depth of their banks is 10 to 20 feet, yet the minimum surface widths of such streams is but 50 to 100 feet and their average depth one-half to 1½ feet during their minimum discharge. In maximum flood such streams reach discharges aggregating 5,000 to 10,000 second-feet, in some cases even more, as shown by their wide, rocky, dry beds.

To convey a clearer idea of the size and regimen of the rivers of Puerto Rico, the following results of rough gagings of such streams as were examined in the preliminary reconnaissance of the island are given. As these streams were observed in the middle of the dry season their discharges may be taken as showing the average minimum volumes which they carry.

The Rio Loiza, probably the largest on the island, was gaged near Carolina, about 15 miles east of San Juan. Its surface width was 220 feet, its average depth 3 feet, and its minimum discharge 1,600 second-feet. (See Pl. VIII, *C*.)

The Rio Canovanas, above its junction with the Loiza, 5 miles east of Carolina, has a bed width of 60 feet, average depth 2 feet, average velocity about 5 feet per second, and discharge 600 second-feet. (See Pl. II, *C*.) This amount is to be added to the discharge of the Loiza to give the volume of the latter at its mouth.

At Caguas, about 20 miles by road south of San Juan, and 230 feet above sea level, the Rio Caguitas, one of the principal branches of the Loiza, flows in long, meandering curves through a level alluvial valley, and carries a minimum volume of about 50 second-feet. A few miles beyond, and in the same valley, the Rio Turabo, another branch of the Loiza, is of similar character and discharges an equal volume.

The Rio Carite, at the crossing of the military road, 36 miles from San Juan, and in the Vegas or plain of Cayey, has an elevation of

A, PARTING VALLEY ABOUT AND HILLS BACK OF YAUCO.

B, ARID FLORA NEAR LARES.

C, FORDING RIO LOIZA NEAR CAROLINA.

D, RIO PORTUGUES AT PONCE.

about 1,180 feet above sea level. This is a branch of the Rio Plata, and its discharge at this point is about the same as those of the two last-mentioned streams, namely, 50 second-feet, though because of its greater altitude, and consequently greater slope, the cross section of its channel is smaller.

The Rio Plata, at a point 4 miles northwest of Cayey, at an altitude of 810 feet, has a bed width of about 100 feet, a depth of 1½ feet and a discharge of 230 second-feet.

South of the main divide at Aibonito, the Rio Calabasas, 4 miles east of its junction with the Rio Coamo at Coamo and at an elevation of 480 feet, has a velocity of 3 feet per second and a discharge of but 25 second-feet.

The Rio Coamo, at the city of that name, and at 360 feet above sea level, has a bed width of 100 feet, though its surface width is somewhat less. Its depth is but 4 inches and its discharge 100 second-feet.

The Rio Descalabrado, halfway between Coamo and Juana Diaz, at an elevation of 260 feet, has a comparatively dry bed of 120 feet width. Its velocity is but 2 feet per second and its discharge 40 second-feet. (See Pl. IX, *A*.)

The Rio Jacaguas at Juana Diaz, elevation 160 feet, has a bed width of 180 feet, a minimum surface width of 50 feet, and a discharge of 50 second-feet. (See Pl. III, *B*.)

The Rio Portugues at Ponce has a bed width of 175 feet, yet its minimum discharge is but 60 second-feet. (See Pl. VIII, *D*.) Its total available discharge is considerably greater than this, but the remainder of its volume is diverted a few miles above for irrigation and for the water supply of Ponce. The same is in a measure true of the Rio Jacaguas, a portion of the discharge of which is utilized for irrigation above the military road.

The Rio Magueyes, at the crossing of the road from Ponce to Adjuntas, 5 miles north of Ponce, elevation 400 feet, has a minimum discharge of 35 second-feet.

The Rio Portugues, at the crossing of the above-named road, near its headwaters, 9 miles north of Ponce, elevation 1,000 feet, has a minimum discharge of 25 second-feet.

The Rio Arecibo, near its headwaters, at Adjuntas, altitude 1,440 feet, has a minimum discharge of 40 second-feet. A few miles lower down, at Utuado, its discharge is 100 second-feet. This river, like the others described, discharges relatively increased volumes in its lower reaches near the coast.

The Rio Yahueca, one of the headwaters of the Rios Blanco and Pietro, or, as they are called near the coast, the Rio Añasco, has, at an elevation of 1,440 feet, about 5 miles west of Adjuntas, a minimum discharge of 20 second-feet.

The Rio Blanco, into which the Rio Yahueca discharges, at an elevation of 1,350 feet, about 8 miles west of Adjuntas, has a minimum volume of about 50 second-feet.

The Rio Culebrina, near the middle of its course at San Sebastian, elevation 140 feet, has a bed width of 125 feet, a considerably less surface width, a velocity of 4 feet per second, and a minimum discharge of 100 second-feet.

The Rio Añasco, halfway between San Sebastian and Añasco, at a point about 8 miles from the latter city, has, at an elevation of 80 feet, a bed width of 150 feet, a surface width of 75 feet, a depth of 1½ feet, and a discharge of nearly 600 second-feet. (See Pl. IX, *B*.) The same river below the city of Añasco flows through a level playa and has an easy, meandering course, its grade being so low as to render its velocity very slow. Its surface width is here about 200 feet, its depth 4 to 8 feet, and its discharge about 1,000 second-feet.

IRRIGATION.

It is evident that all the crops which the soil will produce can be grown over three-fourths of the extent of the island with the aid of the abundant rainfall alone. The other one-fourth, including all the region near the coast and from Cabo Rojo on the extreme west to beyond Guayama on the east, must be irrigated if the soil is to produce the full measure of crops of which it is capable. The total area of these irrigable lands is, however, relatively small. A portion of this one-fourth, or, in round numbers, of the 800 arid square miles, is included within the steepest portions of the southern mountain slopes. Another portion consists of the rugged foothills which, as they rise in detached summits, it is impossible to reach with a gravity water supply. Still another portion of this area consists of the alluvial playas, which produce fairly abundant crops with the aid of the moisture which they draw through their roots from a soil which is but a few feet above the level of the sea. Of the 450 square miles included within the southern back-coast border, perhaps 150 consist of playa lands which need not be irrigated, and 300 more consist of detached and inaccessible hills and of the precipitous slopes of the sierra. There remain, accordingly, perhaps a total of 150 square miles which would add to the agricultural resources of the island if artificially provided with water.

The soil on these lands is in every case of the very best kind for agriculture with irrigation. It is usually an open, porous, limestone soil of sandy and gravelly texture, mixed with a little earthy loam. It is fairly deep and is underlain by a porous limestone or coral, which affords the best drainage and probably renders it safe from the danger of producing alkali. Much of it is already under cultivation in maize, beans, pease, and other lentils in the southwestern extremity of the island, and small vegetables and fruits elsewhere.

While the precipitation is insufficient, the perennial flow of the streams is unusually abundant for a land requiring irrigation. The minimum discharges of these streams where they would be diverted in

A. RIO DESCALABRADO.

B, RIO AÑASCO.

C. REGULATOR GATE AND DITCH.

D. WING DAM.

the foothills are moderate in amount and yet nearly sufficient for the irrigation of such areas as they command. Moreover, the flood discharges of these streams occur at frequent intervals throughout the year, but are especially well distributed throughout the summer or rainy season. They afford an abundant surplus for storage. The shapes of the smaller parting valleys and of the lower canyons through which the rivers emerge from the mountains give every indication that abundant opportunities will be found, on fuller investigation, for the construction of storage reservoirs at moderate expense and at relatively small cost.

The Spaniards, who in the past have been the principal landholders, are thoroughly familiar with the requirements and processes of irrigation as practiced in Spain. Quick to appreciate the advantages of the artificial application of water, they have already constructed numerous ditches of moderate sizes, and much of the more valuable sugar land, especially between Guayama and Ponce, is cultivated exclusively by the aid of irrigation. Much as has been done already in this direction, there is still room for further development. But a portion of the available water supply has been appropriated, and but a small portion of irrigable lands are artificially supplied with water.

Such works as were noted correspond in general type to those seen in Mexico, but because of the greater influence of European ideas in this island, their construction is of a more substantial character, and more nearly approaches that prevalent in Spain and Italy. The diversion works are in every instance of the crudest kind, simple wing dams of rock and bowlders thrown out into the beds of the streams to direct a portion of the waters into the heads of the ditches. These are necessarily carried away by each flood, requiring to be immediately replaced. On the other hand, the headworks, falls, regulating gates, and other dividers are constructed in the most substantial manner of massive masonry.

In strong contrast to this type of construction are the minor distributaries observed in some of the cane fields. These were built by owners who had great grinding and boiling machinery for the treatment of their cane, and were imbued to a certain extent with American methods. They out-Americanized our Western irrigators. Their distributaries consist of a series of temporary trestles and shallow wooden troughs or gutters made of lumber brought from America. These tap the hillside ditches at such points as seem desirable, and are roughly placed so as to carry the water to such portions of the field as immediately require it. After irrigation in such localities the trestles and troughs are removed and utilized in irrigating other portions of the same fields. This practice is resorted to in order to reach the numerous little detached rolling hills 10 to 20 feet in maximum height, into which the surface of the sugar lands is broken. In

other localities, where practicable, these lands are irrigated by direct diversion from the main ditches of laterals dug in the earth and ramifying to every portion of the field to which gravity will conduct the water.

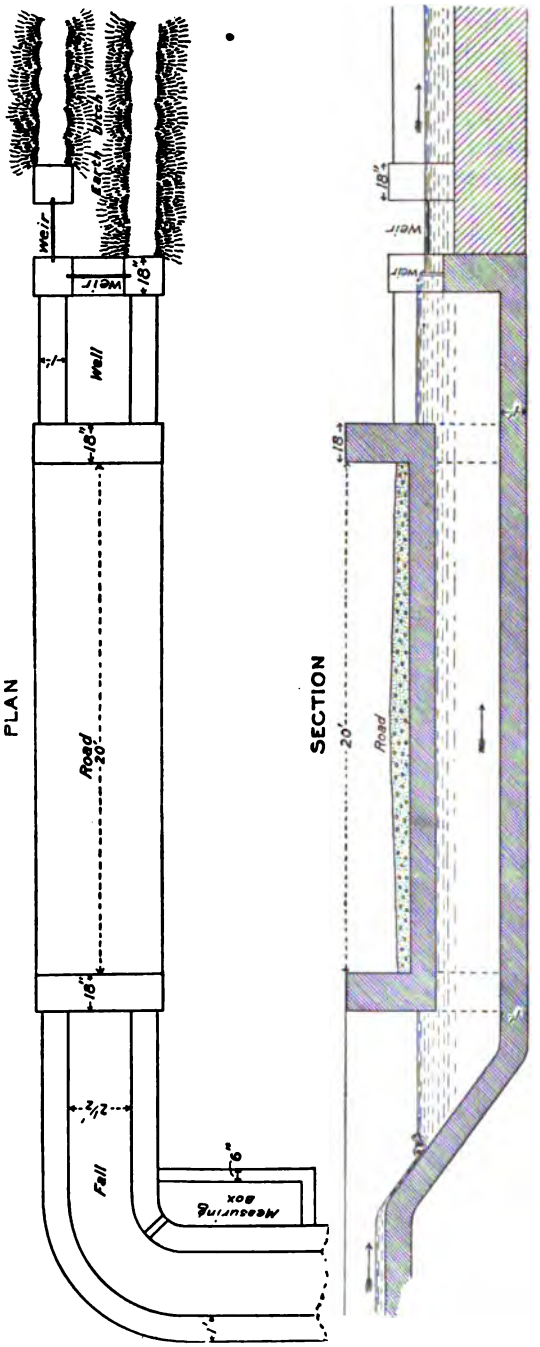

FIG. 6.—Inverted siphon carrying ditch under military road.

Immediately to the west of Juana Diaz the most important irrigation work noted on the island is a ditch from the Rio Jacaguas. The point of diversion is in a narrow gorge, well up in the foothills, about 5 miles above the military road. The ditch thence is about 5 feet in width at the top, 3 feet in depth, and is excavated in the earth slopes of the hillsides, around which it is well graded. This ditch is divided into numerous distributaries, all of the simplest earth construction, which convey its waters to every part of the cane fields.

Farther west another irrigation ditch is carried under the military road in an inverted siphon of masonry (see fig. 6), which is similar in all respects to such structures seen in India and southern Europe.

The width of the masonry channel at the entrance of the siphon is but 2½ feet and its extreme depth 18 inches. The water

slides down an incline at an angle of about 45° to a depth of about 6 feet below the level of the ditch bank, and is carried thence under the road in a rectangular masonry conduit. Near the entrance to this chute is a little masonry measuring box 3 inches in depth, from which water flows through a lip in the top of the conduit. The walls of the main conduit are a foot in thickness, and at their exit on the lower side are buttressed by square blocks 18 inches in cross section. In these are grooves for inserting flashboards, by which the amount of water passed into the canal beyond can be measured as over a

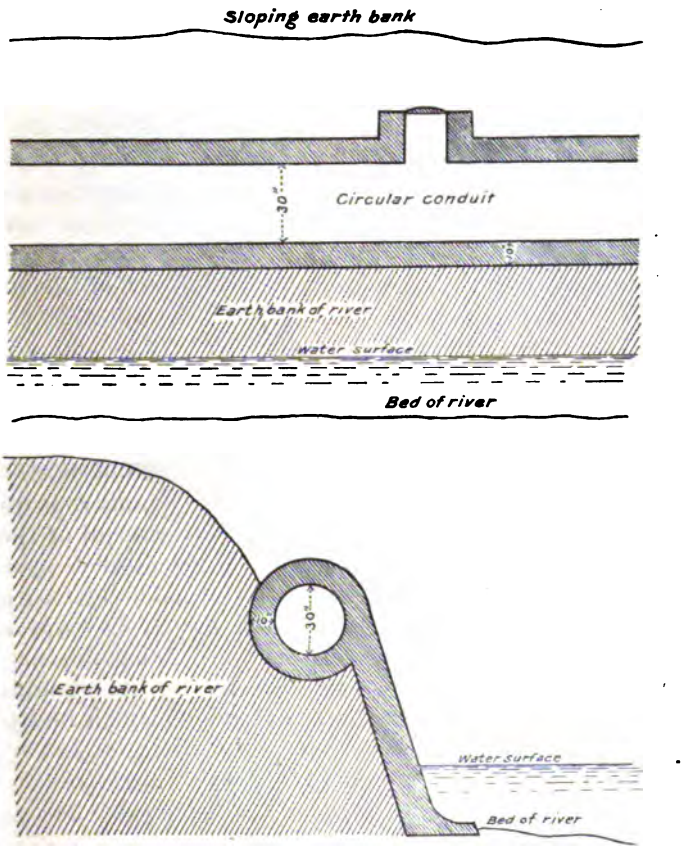

FIG. 7.—Masonry conduit and retaining wall; longitudinal and transverse sections.

weir, while at the same time the supply is regulated. (See Pl. IX, *C*.) Below this a lateral is diverted through gates identical in type.

Near this place was seen a rough wing dam of rock, which diverts a stream into a substantial masonry conduit (see Pl. IX, *D*), whence it is led along the banks of the river through a circular masonry pipe 30 inches in diameter and 10 inches thick (see fig. 7), in many places close to the river bank. To protect it from the erosive action

of floods, the conduit is supported on a heavy retaining wall of masonry until at some distance a sufficient grade is attained to carry it away from the banks of the stream. (See Pl. X, *A*.)

AGRICULTURAL LANDS AND SOIL.

The parting valleys, and especially the playa plains, are often quite extensive, and constitute the chief portion of the more valuable sugar and grass lands which border the entire coast. The larger of these agricultural plains are to the eastward of San Juan as far as Luquilla, and include wide indentations which extend up the valley of the Rio Loiza. There are smaller playas between Fajardo and Humacoa and between Guayama and Ponce. (See Pl. X, *C*.) West of San Juan the playas are not so extensive until beyond the mouth of Rio Cibua, between which and Arecibo are some large areas of playa land. Thence westward there is no coast border of any moment until Aguadilla is reached, but there, as well as at Añasco, are two fairly extensive playas. The remaining sugar lands are those in the larger parting valleys, some of which are of great extent. Those between Yauco, Sabana Grande, and Hormigueros are the largest, but some of the others contain 1,000 to 5,000 acres each.

In addition to the cultivable areas which may be added by irrigation, much waste swamp land may be reclaimed by drainage. This is especially true of the playa lands about the coast lagoons and of some of the swampy valley lands near the head waters of the Rio Loiza and Rio Plata, which are now chiefly covered with guinea grass. (See Pl. X, *D*.) One such swamp alone, near Guanica, contains 8,000 acres of reclaimable land belonging to the Government.

There are two other distinct types of agricultural lands on the island. These are found in a few small alluvial valleys on the upper courses of the rivers, as at Caguas (see Pl. IV, *B*), Cayey, and Sabana del Palmar, and in the main mass of fruit and coffee land on the slopes, reaching even to the crests of the highest summits of the sierra. The mountain valleys appear frequently to have been old abandoned lake beds, and are extensively cultivated in forage grass and in tobacco. The most interesting agricultural feature of the island is, however, the steep slopes of the main cordillera, which are everywhere cultivated and are mantled with sufficient depth of soil to give firm hold to the luxuriant vegetation with which they are covered. (See Pl. XI, *A*; text fig. 8, on page 37; and Pl. IV, *C*.)

The soil of Puerto Rico, in physical and chemical composition, is of two kinds. It is these differences which furnish the most radical changes in flora observed on the north and on the south side of the island, modified, of course, by altitude to a less extent and by precipitation to the greatest extent. Primarily the soils are either of calcareous or of clay origin, the result of decomposition of the underlying rock.

A, RIVER BED AND MASONRY CONDUIT.

B, IRRIGATION DITCH IN EARTH.

C, SUGAR LAND NEAR PONCE.

D, GUINEA GRASS, CAGUAS VALLEY.

deposits of guano on Mona Island, just off the west coast, and smaller deposits in caverns on the west coast and near Ponce. Elsewhere throughout the island are great beds of shell and chalk marls and of lime phosphates. The lime marls are abundant everywhere around the coast, and gypsum marls occur in the neighborhood of Ponce.

AGRICULTURAL PRODUCTS.

The soil of Puerto Rico is so deep and fertile, the precipitation so abundant and well distributed, and the temperature, though tropic, so mild as to render it possible to cultivate almost all the land on the island. Moreover, almost every foot of it is now or has been under cultivation. It is essentially the land of the small farmer, because, limited as the island is in extent, the official records show that it is divided into 36,650 individual holdings. These are distributed as follows: Tobacco plantations, 66; cattle ranches, 240; coffee plantations, 360; sugar plantations, 435; small coffee farms, 4,185; small farms of mixed coffee, fruit, and vegetables, 4,375; small fruit and vegetable farms, 16,990. At least 21,000 of these holdings are of the smallest kind, being owned by the poorer peasantry. Such holdings range in size from 5 to 50 acres, rarely reaching the latter amount. The remaining 5,000 holdings are from 100 to 5,000 acres or even larger. The greater proportion of these are relatively small and are devoted chiefly to the cultivation of coffee, the larger ones being mostly cultivated in sugar.

So fruitful are the soil and climate that the people pass an indolent and lazy existence, even to a greater extent than is observable elsewhere in Spanish America. Outside of the few large plantations the people are unacquainted with any agricultural implement other than the machete, a short thick sword, which serves all the purposes of scythe, brush hook, ax, hoe, and weapon of defense. Holes are scratched in the surface of the soil in which to plant seeds or transplant sprouts. Thereafter no attention is given to the crop until it becomes necessary to gather the product either for domestic consumption or for exchange in the nearest village for such household necessities as the farm does not produce.

Abundant and well distributed as are the various crops, the island produces to but a fraction of its capacity. (See Pl. XIII.) Thus far there has been no incentive to grow such products as would have value for export, and no means have been available and no forces at work to incite the ambition of the people, and thus give them some inducement to gain a better living. They know nothing of the higher arts of civilization, and if they had more wealth than they now possess they would not know how to use it. With the higher aims which will come from association with the more active, liberal, and highly civilized people of the United States, increased energy may be exerted in

A, MOUNTAIN SUMMITS UNDER CULTIVATION.

B, OX CART.

C, SADDLE AND PACK HORSE.

D, HOGS LED BY ROPE.

the near future in wresting from nature more bountiful and useful crops than are now cultivated.

At present such crops as are produced for exportation are limited almost exclusively to sugar and the by-products of the cane (molasses and rum), coffee, tobacco, and hides, in the order named. In value, however, coffee exceeds that of sugar in the ratio of three to one. According to the Spanish Estadistica General, the total exports for 1897 were valued at $18,574,678. These were distributed as follows:

Exports of principal articles from Puerto Rico, 1897.

	Amount, in pounds.	Value.
Cane sugar	125,323,589	$4,007,999
Molasses	25,085,069	403,519
Coffee	51,097,823	12,222,598
Tobacco	6,181,771	1,194,318
Hides	822,108	71,852
Other articles		674,392
Total		$18,574,678

In addition to the above there are several other articles of export which, like these, are all of agricultural origin. In order of importance they are: Honey, the value of the exported product being $517,746; wax; cattle, of which 3,180 head were exported; chocolate; straw hats; and a very small amount of fresh fruit.

From the above it is evident that the most valuable crop of the island is coffee. Next in importance ranks sugar and then tobacco and cattle. In addition there are cultivated, chiefly for domestic consumption, various cereals, lentils, potatoes, small vegetables, and fruits, as well as forage grasses.

Of domestic animals cattle are first in importance. These are of unusually large size, being far more powerful and heavier than any seen in Central or tropic South America or elsewhere in the West Indies, and in fact exceed in size the cattle of our Southern States. They have widespreading horns and in general appearance they resemble the range stock of Texas and the uplands of Mexico. (See Pl. XII, *B*.) Horses are abundant, but are so diminutive in size as to scarcely deserve any other name than pony. They resemble in general appearance the ponies of Cuba, but though small they are exceedingly hardy and are excellent pack animals. (See Pl. XI, *C*.)

All the heavy draft work of the island is done by oxen, which are yoked, not by the neck but by the horns, to heavy two-wheeled bullock carts made of mahogany and similar hard woods. (See Pl. XI, *B*.) Off the roads, and these are but few and inferior in quality, all produce is hauled to the markets and purchases made there are carried

back to the mountain farms on the backs of the sturdy little pack horses which climb with sure foot the steep, wet, and slippery trails. (See Pl. XI, *C*.) The method of packing these animals is that commonly practiced in some portions of South America. Most burdens are carried, not by means of pack saddles or of aparejos and lash ropes, but in wicker-basket panniers, which are hung loosely over the backs of the animals. Sacks of coffee, however, are hung loosely by sling ropes. In this way they are loaded with 150 to 250 pounds of coffee or other burden and tramp with quick, short steps over the rugged trails.

In addition to cattle and horses a very few small mules are bred; the only other domestic animals are poultry, hogs, and dogs. The poultry are of inferior breed, being chiefly raised for the game cocks, which are used in the universal sport of the people. These and the hogs, which are also of small size and of poor breed (see Pl. XI, *D*), thrive well, but are so few in number that fences are rarely built to restrain them. It is therefore a common sight to see hogs tethered by a string tied around one leg and attached to a tree or picket, and to see poultry tied in the same manner and forage much as do milch cows.

The various agricultural crops of importance are distributed in zones, depending on and clearly marking the variations in altitude, rainfall, and soil composition. Sugar cane is cultivated exclusively in the coast playas and in the parting valleys among the lower hills of the back-coast border. It grows luxuriantly, the stalks being 10 to 15 feet in height and often 2½ inches in diameter at the base. (See Pl. XII, *A*.) The cane is cut during the months of January to March, inclusive, and produces an average yield of 3 tons to the acre. It is the only crop except coffee, the latter to a more limited extent, which is cultivated with modern methods and harvested by the use of modern machinery. Heavy, imported metal plows, drawn by six to ten yoke of oxen, are used in tilling the soil and making the furrows, through which irrigation water is flowed. The cane is cut down with a blow of a machete, and the longer stalks cut into lengths of 3 to 4 feet by the same process. It is carted from the field to the sugar mill either in ox carts (see Pl. XI, *B*) or occasionally on trains of cars, hauled by oxen over railways placed temporarily in various avenues through the cane fields (see Pl. XII, *B*). The roadbed of these tramways is laid permanently, but the rails and ties are moved about as required. The sugar mills are invariably substantial brick structures containing the most modern machinery, in which the cane is crushed, boiled, and evaporated. From the mills cane sugar of muscovada grade, molasses, and rum are shipped, the last being usually distilled in the same mills.

Tobacco of excellent quality thrives well everywhere. The best varieties, cultivated in sufficient quantities for export, are grown chiefly in the valleys and the river bottoms on the head waters of the Rios Loiza and Plata. The culture of tobacco is especially exten-

A, SUGAR CANE.

B, TRAIN OF CARS LOADED WITH SUGAR CANE DRAWN BY OXEN.

C. COFFEE SHADE.

D SHELLING COFFEE

sive in the valleys and on the mountain slopes about Caguas, Cayey, Comeiro, and Juncos. (See Pl. IV, *B*.) Especially interesting is its cultivation on the steepest slopes of the higher hills. (See fig. 8.) There groups of ten to twenty laborers may be seen clinging like ants to the steep mountain sides, hoeing and weeding or gathering the crop.

These tobacco fields are the best kept and the most industriously attended agricultural products observed on the island. The flavor of the tobacco grown in the region named is excellent. It is sold in Puerto Rico at about $25 to $30 per hundredweight. The larger portion of it is shipped to the United States and Europe, through Cuba, where it passes as Habana tobacco of the highly prized Vuelto Abajo quality. In Habana it commands $100 to $125 per hundredweight.

Coffee is grown everywhere on the island at altitudes above 1,000

FIG. 8.—Cultivated hill tops in Cayey tobacco district.

feet. Ordinarily it is at present cultivated at too low an altitude to yield the best variety and so little attention is given it in the way of cultivation and fertilization that the yield is relatively small. At altitudes of 1,000 to 1,500 feet the average product is about 500 to 600 pounds per acre. Between 1,500 and 2,000 feet the yield is 600 to 800 pounds per acre. Above 2,000 feet yields of 1,000 to 1,200 pounds per acre are occasionally obtained, for at such altitudes coffee is generally grown by the larger planters and under more intelligent supervision. The product would be greatly increased and the quality improved if better methods of cultivation were employed and if the crop were more extensively grown on the higher summits. The coffee plant is very delicate and is invariably shaded by tall, wide-spreading trees, chiefly the guayava, guama, and maga (see Pl. XII, *C*), which are planted for this purpose, and only occasionally, as is the custom elsewhere in the West Indies, is the plant shaded by bananas and plaintains. These latter are, however, chiefly used as shade for the younger coffee plants before they reach the yielding age.

The coffee plant is not unlike a tall, slender currant bush in general appearance, though it is peculiarly devoid of leaves or branches. Several stems grow from one root, and these are but three-quarters to an inch in diameter at the base, although they are 8 to 12 feet in height. They put out little, short branches with small leaves, and on these branches grow the coffee beans with exceedingly short stems, so that they appear to cling closely to the wood. The coffee berry when ripe is not unlike a good-sized red cherry. The plant begins to bear after four years, and the berry is picked during the winter months, from October to February. It yields best in seven to eight years and continues to produce for about thirty years. The berry is gathered chiefly by women and children, who empty their small basketfuls into

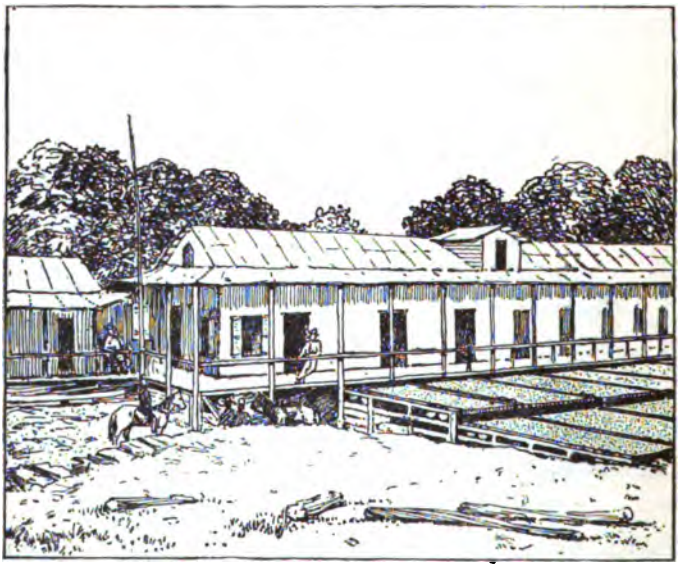

FIG. 9.—Drying coffee on rolling platforms, Pietris Plantation, Adjuntas.

larger baskets or sacks, and these are carried by men to the drying platforms, where the coffee remains in the sunshine, but always protected from rain and night dew, until thoroughly dry. The drying platforms are of two general types. The first type consists of broad, level platforms of masonry, with smooth concrete surfaces on which the berries are spread out evenly and are hoed over, and from which they are gathered and placed under cover at night or when rain threatens. The second variety of platform, that used on the larger plantations, consists of large wooden trays about 8 by 12 feet. These rest on rollers which run on tracks in such manner that when it is necessary to place the coffee under shelter the trays are rolled under the coffee house; as the trays are but 5 to 7 inches in depth, they run one above another, so that usually three trays, and sometimes more, are housed under one portion of the coffee house. (See fig. 9.) Not

infrequently coffee is dried in the streets or plazas by spreading it out on burlap sacking, which can be quickly gathered up in the form of a bag and carried away.

After drying, the berry is crushed in great wooden mortars with heavy wooden pestles, so as to break away the dried husk which incloses the coffee bean. (See Pl. XII, *D.*) Where better managed this crushing is performed in a circular trough not unlike an arastra, by means of heavy wooden wheels which are turned by animal power and sometimes by water power. After crushing, the coffee is washed and screened to separate the bean from the husk. The former is usually double—that is, there are two half beans within one berry. Not infrequently, however, it consists of one deformed bean which is egg shaped and smaller than the two halves. This variety is called "caricolillas," and is especially prized in European markets. The washed coffee beans are placed in airy rooms in the drying houses and thoroughly seasoned and dried before shipping.

The variety grown generally is of excellent flavor. As yet little of it reaches the American market, chiefly because of the export duty now placed on it and because it commands a much higher price in the European than in the American market. The better varieties are sold by the sack by commission merchants in Puerto Rico at 13 to 18 cents per pound. This is a higher price in Puerto Rico than is paid in New York by coffee importers for the best grades of Bogata, Caracas, and other fine Central American varieties. As it is not well known in the American market, importers will not offer more than 10 to 12 cents for it. Much of it, however, reaches the United States, chiefly that of the poorer grades, being shipped to Europe in transit. After it has remained some time in the bonded warehouses it is withdrawn under the names of Java and Mocha. The American coffee buyer purchases largely on the appearance of the bean, and accepts that which has a dull and lusterless appearance. In Europe, however, coffee having a bright gloss is preferred, and for this reason Puerto Rican coffee is at present extensively treated with a wash of gum arabic and charcoal or some similar preparation, which gives it this gloss. This process injures the sale of the article in the American market. Those who have used Puerto Rican coffee, however, insist that its flavor is equal to the best sold in the country, and that when better known it will command a higher price and will displace the very best of the Central American product.

Other valuable agricultural products are forage plants. The most important variety is guinea grass, a succulent plant having a blade or leaf 2 to 3 feet in height and fully one-half inch in width. It yields about 3 tons to the acre and grows quickly and luxuriantly. (See Pl. XV, *D*, and Pl. X, *D.*) Cattle and horses thrive on it and on a nutritious, leguminous plant called "malahojilla," which is a variety of the wild-pea pine. On the southern foothills the chief forage plant is

a short, dry-looking grass, not unlike the Southwestern bunch or buffalo grass. (See Pl. VI.) The leaf and stalk of maize and the pods of various acacias, which are gathered green, are also used.

Maize is grown extensively in the wide parting valleys in the southwestern portion of the island. In the same region and in the beds of many of the streams which flow into the west coast, lentils are grown in large quantities. There are a number of varieties of these, chiefly beans, including the green string bean and the white and liver-colored bean, which when cooked are the "frijole" of Spanish America and the "Boston baked bean" of the United States. A lentil-like berry, which in appearance is between a pea and a small bean, and yet grows on a bush belonging to the acacia tribe, is the guadure, and this is very extensively grown for domestic consumption on the semi-humid side of the island. It occurs in a pod about 3 to 4 inches in length on a bush 6 to 8 feet in height. Yams and sweet potatoes are grown extensively, generally for home consumption, and Irish potatoes thrive well, but are grown to only limited extent in some portions of the uplands. Among other small vegetables are tomatoes and red pepper.

Cotton seems to flourish well, though it is not cultivated in commercial quantities. The cotton plants noted were almost as large as apple trees, being from 8 to 12 feet in height, with a stem 2 to 3 inches in diameter at the base. (See Pl. XIV, *A*.) The flowers and pods were numerous, and the latter well filled with a long staple cotton apparently as fine as the best grown in the Southern States.

A variety of upland rice peculiar to the island is cultivated in the interior hills, and grows without irrigation or inundation. At present but little is produced, because the Spanish have discouraged its cultivation in order to increase the importation of rice from Spain. A plant called the yautia is one of the staple vegetable foods of the people, and is grown on the humid side of the island in large fields, much as cabbage is cultivated in the United States. It is the *Caladium esculentum*, and grows to a height of 2 to 3 feet. It consists chiefly of wide-spreading, heavy, green leaves, 12 to 20 inches in length, in appearance not unlike those of the plantain. (See Pl. XV, *A*.) These are stewed and eaten as is cabbage or spinach, or are boiled as is okra in soups.

Another staple food is the plantain, which is baked when green, and is the bread of the people. There are many varieties of plantains and bananas, both cultivated and wild. No attempt seems to have been made, however, to grow those varieties which are in favor in the markets of the United States or Europe, and none are, therefore, exported. This should become one of the greatest of the agricultural products of the island, both for home consumption and for export, when means of rapidly conveying the same to the coast are available through the construction of good highways, and when the people

A, COTTON PLANT

B, MARKET SCENE, PONCE.

C, LOGS OF AUSUBO EN ROUTE TO MARKET.

D, REPAIRING MILITARY ROAD.

learn to produce such varieties as are in demand abroad. The seed stock at present used is poor and run out, the bananas yielding only 2 or 3 hands deep instead of 10 to 15 hands, as they must for export.

Bananas and plaintains are grown generally throughout the island. They are cultivated most extensively on the hill slopes, being rarely seen on the alluvial lands and in the valley bottoms. On the humid side of the island these plants are, with cocoanut palms, the most prominent features of the landscape. (See Pl. VII, *B*.) They are scattered on every hillside, being grown sometimes in orchards, but more generally in various portions of fields with other crops and in gardens. On the arid side of the island they are seen less frequently and at the lower altitudes quite rarely.

Another of the more abundant and valuable fruit trees is the cocoanut palm. The fruit is large sized and well flavored, and extensively consumed when green. But little is exported, though the husks are, to a moderate extent. This tree also flourishes everywhere and produces well.

Oranges, like bananas and cocoanuts, grow wild and cultivated everywhere with great luxuriance; so also do lemons and limes. A cultivated variety of oranges, which is used to a small extent in shading coffee, is unusually juicy and well flavored and is the equal of the best produced in the United States. Yet none are exported, and such few as are gathered are a drug on the home market and are sold at the rate of from two to three for one cent.

Pineapples are cultivated to a slight extent, chiefly in the southwest, about Cabo Rojo. Guayavas also are chiefly grown in the southwestern portion of the island, though they are not cultivated to the extent one would expect. From them is made guayava jelly, which is a popular confection with the inhabitants and finds also ready market in the United States. Less abundant are the aguacate or alligator pear (Persea), the guanavana, called in Central America "chiramolla" and "custard apple" (Anona); the mango, the mamey or bread fruit (Mammea), and a variety of others. All of these fruits and vegetables are extensively consumed by the people and are for sale in all the city markets. (See Pl. XIV, *B*.)

FORESTRY.

The forest resources of the island have been practically exhausted. The country has been so long densely inhabited and under cultivation that practically all the virgin timber has been removed, and some of the native trees are so rare that specimens of them can scarcely be found. Practically all of the more valuable hard woods, which are abundant in Haiti and eastern Cuba, are indigenous on this island. The whole surface of the country, especially on the higher mountain slopes, is well covered with trees. The woods consist chiefly of the artificial and natural shade trees, under which coffee is

planted. (See Pl. XII, *C.*) The more important of these trees are the guama (*Inga laurinea*), guava (*Inga vera*), bucare (*Erythrina bucare*), and maga (*Thespesia grandiflora*). These trees are of little value for their lumber, as their trunks are but 4 to 7 inches in diameter, are not straight, and branch about 10 to 15 feet from the ground, reaching a height of 30 to 50 feet. The maga has some value for timber; the wood is hard, can be worked without great difficulty, and is used to a limited extent in the construction of furniture and for similar purposes.

The most abundant of the precious hard woods is the ausubo, resembling teak or mahogany. Trees of this kind are found in many portions of the island, and it is used extensively in making bullock carts, the spokes and poles of these being always of ausubo. It is also used for beams, rafters, and upright posts in buildings. Two varieties of Spanish cedar, the hard and soft cedar, occur, but both are rare—a 12-inch plank, 1 inch thick and 12 feet long, being valued in the mountains at $1. Another of the more abundant woods is the guaraguao, which is used chiefly in making board flooring and is valued at about 50 cents per plank. Another wood employed in board flooring is the capa prieta. An excellent furniture wood, strong and hard but very rare, is the capa blanca. The mauricio is a very durable yellow wood used for parts of machinery, for the hubs of carts, and for similar purposes. A wood which does not easily decay, and is therefore used for posts and such purposes as require insertion in the ground, is the higureillo. Among other of the native woods are the nonfragrant sandalwood, laurel, ucar, algarrobo, palosanto, and bamboo. (See Pl. XV, *B.*)

All of these woods are so scarce, however, that the larger portion of the timber used in structures is imported. The most extensive import of wood is common spruce, hemlock, and pine from Nova Scotia. Many of the older buildings of the island are of native woods, but all of those which have been recently constructed have been built chiefly of imported lumber. Only two sawmills of any capacity were seen on the island, one in San Juan and the other in Ponce, and both were engaged in cutting up cedar wood for cigar boxes and in making parts of wagons and of machinery from ausobo. In the mountains in a few places old-fashioned whipsaw pits were seen, at which mahogany planks were being cut out of rough logs. These were then hauled by horses over muddy trails for many miles to the cities in which they were to be used. (See Pl. XIV, *C.*)

Aside from the few scattered hard-wood trees which grow on the slopes of the more inaccessible mountains there are a few rather extensive pieces of woodland. The most important of these is on the eastern end of the Sierra de Luquilla, which is heavily covered with virgin forest. East of Ponce, about Santa Isabel and Salinas and in the extreme southwest near Cabo Rojo, are some extensive areas of

A MAMEY (BREAD FRUIT) TREE IN FIELD OF YAUTIA RIO CANOVANAS.

B, CLUMP OF BAMBOO, 60 FEET HIGH.

C, NEAR SUMMIT OF SIERRA DE LUQUILLA

D CEIBA TREE IN FIELD OF GUINEA GRASS.

woodland. The amount of merchantable timber which is left, however, is too small to render this an important element among the natural resources of the island.

WATER POWER AND SUPPLY.

The volume of water available for utilization either as supply for domestic purposes in the various cities or for conversion into power through the agency of water wheels is relatively great. While this is especially true of the north side of the island, it applies also in a measurable degree to the south side, for, while on the latter side the streams do not discharge large volumes during the dry season, there is more water in them near their sources in the mountains than reaches the lowlands, because of loss through evaporation and percolation.

All of the cities of any size are provided with some form of domestic supply. At present, in San Juan, this is chiefly from rainfall. The same is true of most of the cities which are on the humid side of the island, though in some cases the rain water which is caught in tanks is supplemented by gravity supplies. In no city, however, is there a water supply of modern type at all commensurate with the requirements of a tropic climate. Not only is the supply for domestic use insufficient in every case, but there is practically no supply available for fire engines, for the flushing of house plumbing, or for washing streets and flushing gutters.

A new water supply is being provided for the city of San Juan. This was commenced under the Spanish authorities and is now being pushed to completion by officers of the United States. It is well designed after several years of survey and investigation. The supply comes from the Rio Piedras, about 6 miles above San Juan, where it is diverted into a short canal, which carries it into settling reservoirs, each of which has a capacity of one and one-half days' supply, at the rate of 35 gallons per head. Thence the water flows into filter beds, whence it is pumped to a distributing reservoir 110 feet high. From this it will be conducted in underground mains and distributaries to the various houses in the city.

Ponce receives a gravity water supply from the Rio Portugues, whence it is diverted about 9 miles above the city and conducted in masonry conduits and underground iron distributaries to the more important streets. On a hill back of the hospital in the outskirts of Ponce is a small, covered, distributing reservoir. This has not been cleaned in many years and is so foul that its use has been abandoned. Mayaguez, which is in fact the best provided city on the island, also receives a gravity supply. This is from the Rio Mayaguez, the perennial discharge of which is sufficient for the present requirements of the inhabitants.

Most of the smaller cities, as Aibonito, Adjuntas, Lares, etc., have gravity supplies of water piped to them from neighboring streams, but the volume of water supplied is rarely greater than can be easily carried in a 2-inch pipe. No difficulty either of an engineering or financial nature should be encountered in supplying these cities with abundant quantities of wholesome, potable water. Near every city there is sufficient water available in one or more of the rivers, and this can invariably be diverted at sufficient altitude to permit its being carried by gravity into the cities. The natural conditions in nearly every case are such as should insure the procurement of such water supplies at relatively small cost.

The opportunities for the generation of power are also superabundant, and the use which has thus far been made of them is insignificant. The amount of water available for conversion into power is evident from a consideration of the discharge of the various streams, as already stated, and the great height from which the water falls in but comparatively few miles. Streams which have a minimum volume of 50 to 150 second-feet at an altitude of 1,000 to 1,500 feet fall to within 100 feet of sea level in a distance of 5 to 10 miles. Consequently there are many steep rapids, cascades, and high falls in their courses, and it is necessary to convey the water in flumes or ditches but relatively short distances to obtain such head as will produce all the power of which use can be made. Finally, the width of the banks of these streams within the mountain gorges is so small and their surfaces are composed so largely of rocks and bowlders that there will be little difficulty or expense connected with the diversion of the water through dams and head works. Already one American corporation has purchased and obtained control of one or more water powers on the Rios Plata and Arecibo. The amount of power which will be obtained from these has been estimated as from 500 to 1,000 horse-power per concession.

TRANSPORTATION FACILITIES.

The development of the agricultural resources of the island is necessarily dependent largely on facilities for transporting products to the coast for shipment and of returning thence purchases made in the coast towns. At present the island is less adequately provided with good wagon roads than is the more sparsely inhabited and most inaccessible portion of the mountainous Western States. There is but one good road across the island and some pieces of fairly good road around the coast. The latter are, however, disconnected. In addition, there are about the coast several long but disconnected pieces of railroad. The railroads are of French construction and operation. They are of very narrow gage, 1 meter or less. There are about 140 miles of such railroad in operation, including a short stretch from San Juan eastward to Carolina; another from the same point westward

A. MUDDY CART ROAD NEAR ADJUNTAS.

B MUDDY CART ROAD NEAR AIBONITO.

C ROCKY CART ROAD NEAR LARES.

D, RUTTED CORAL ROCK IN CART ROAD NEAR SAN SEBASTIAN.

to a little beyond Arecibo; a section between Aguadilla, Mayaguez, and Hormigueros; one between San Sebastian and Añasco, and another from Ponce to Yauco. The locomotives are light, the cars small and of trifling capacity, and the trains run but once in every day or two and consist of but two or three cars.

The roads are divided into three classes: First, military roads, of which there are about 285 miles. These are all well graded and well surfaced with macadam and are kept in fairly good repair. (Pl. XIV, *D.*) Moreover, they cross the various drainage channels on well-constructed masonry bridges and culverts (see Pl. XVII, *A*), often girdling the mountain sides in great cuts, blasted out of the sides of the precipitous slopes (see fig. 10). Aside from the road from San Juan to Ponce, the other portions of this first-class road are near the coast, including a stretch between Arecibo, Aguadilla, and Mayaguez; another between Mayaguez and Yauco; and still others between Rio Piedras and Carolina and between Caguas, Juncos, Humacao, and Naguabo. A branch of the road which crosses the island extends from Cayey to Guayama. Aside from this limited amount of first-class road none on the island is worthy of being called even second class, though so designated by the Spanish.

FIG. 10.—Rockwork near Aibonito, summit of military road.

There are said to be about 100 miles of second-grade road, including stretches between Arecibo, Utuado, Adjuntas, and Ponce, of which only the latter portion is in condition to carry even the roughest cart traffic. (See Pl. XVI, *A*.) Another bit of cart road, over which only the lightest loads can be drawn by bullock, is between Aguadilla, San Sebastian, and Lares. (See Pl. XVII, *B*.)

The third class of roads, called cart roads, are officially stated as aggregating over 500 miles in length. None of these, however, is fit for other traffic than that of pack animals. Even military roads furnish transportation facilities for only an extremely limited extent of coun-

try to either side. The moment one leaves such roads he is compelled to enter at once on trails which climb the precipitous mountain sides with extremely steep grades or descend into the deep stream gorges.

The great amount of rainfall and the peculiarly slippery and sticky character of the red-clay soil on the humid side of the island renders all roads except those near the southern coast and those which are macadamized little better than impassable morasses. (See Pl. XVI, *B*.) No wheeled conveyance can travel such roads unless they be provided with far better drainage than now. On the drier side of the island, especially over the coral formation at the western end, the roads are filled with great rocks and bowlders (see Pl. XVI, *C*), and in places the soft coral rock is worn into deep ruts, rendering the roads impassable now for carts. (See Pl. XVI, *D*.) On these so-called cart roads even the sturdy pack animals have great difficulty in carrying relatively light burdens through clinging mud ankle deep, or over the bowlder and rock strewn surface.

As the bulk of the present transportation is on pack animals, which carry but 150 to 200 pounds a trip and return half laden, it is interesting to note the present price paid for handling freight in this manner. Between the more distant points over which pack journeys are made $1 per hundredweight is paid each way and 50 cents per hundredweight is the least rate, even for a very short haul. From the neighborhood of Adjuntas to Yauco and Ponce the rate is $1 per hundredweight. One of the largest coffee plantations on the island, that of Mariani Sons, pays from $1 to $1.50 per hundredweight for transportation. Those in the neighborhood of Lares pay as much as $2 per hundredweight for transportation to Mayaguez, and those of Tres Hermenos pay 75 cents per hundredweight. Sugar is conveyed from boiling houses to the nearest shipping points usually in 15-hundredweight hogsheads, which can be carried on bullock carts over the better roads found near the coasts. The cost for such haulage varies from 20 to 30 cents per hundredweight. Inferior as are the railroad facilities, the difference in price is shown by the fact that railroad carriage costs but two-thirds of a cent per hundredweight per mile.

The necessity for the development of a comprehensive system of first-class highways or railways is too evident to require further elaboration. Until such a system is in existence there is little hope for the development of any of the resources of the island except coffee and tobacco, which can be hauled at convenience, since they are not perishable, and sugar, which is grown only near the seacoast and at places convenient to shipping points. The most obvious direction in which improvement of internal means of communications should take place is in the construction of electric tramways as main arteries of traffic, supplemented by macadamized roads as feeders. Material for railway ballast and for road metaling is abundant in every part of the island. This consists chiefly of hard black limestone and of hard coral rock and bowlders.

A, BRIDGE OVER RIO CAÑA NEAR CAGUAS.

B, ROCKY CART ROAD NEAR LARES.

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1895.

Sixteenth Annual Report of the United States Geological Survey, 1894–95, Part II, Papers of an economic character, 1895; octavo, 598 pp.

Contains a paper on the public lands and their water supply, by F. H. Newell, illustrated by a large map showing the relative extent and location of the vacant public lands; also a report on the water resources of a portion of the Great Plains, by Robert Hay.

A geological reconnoissance of northwestern Wyoming, by George H. Eldridge, 1894; octavo, 72 pp. Bulletin No. 119 of the United States Geological Survey; price, 10 cents.

Contains a description of the geologic structure of portions of the Bighorn Range and Bighorn Basin, especially with reference to the coal fields, and remarks upon the water supply and agricultural possibilities.

Report of progress of the division of hydrography for the calendar years 1893 and 1894, by F. H. Newell, 1895; octavo, 176 pp. Bulletin No. 131 of the United States Geological Survey; price, 15 cents.

Contains results of stream measurements at various points, mainly within the arid region, and records of wells in a number of counties in western Nebraska, western Kansas, and eastern Colorado.

1896.

Seventeenth Annual Report of the United States Geological Survey, 1895–96, Part II, Economic geology and hydrography, 1896; octavo, 864 pp.

Contains papers on "The underground water of the Arkansas Valley in eastern Colorado," by G. K. Gilbert; "The water resources of Illinois," by Frank Leverett; and "Preliminary report on the artesian areas of a portion of the Dakotas," by N. H. Darton.

Artesian-well prospects in the Atlantic Coastal Plain region, by N. H. Darton, 1896; octavo, 230 pp., 19 plates. Bulletin No. 138 of the United States Geological Survey; price, 20 cents.

Gives a description of the geologic conditions of the coastal region from Long Island, N. Y., to Georgia, and contains data relating to many of the deep wells.

Report of progress of the division of hydrography for the calendar year 1895, by F. H. Newell, hydrographer in charge, 1896; octavo, 356 pp. Bulletin No. 140 of the United States Geological Survey; price, 25 cents.

Contains a description of the instruments and methods employed in measuring streams and the results of hydrographic investigations in various parts of the United States.

1897.

Eighteenth Annual Report of the United States Geological Survey, 1896–97, Part IV, Hydrography, 1897; octavo, 756 pp.

Contains a "Report of progress of stream measurements for the year 1896," by Arthur P. Davis; "The water resources of Indiana and Ohio," by Frank Leverett; "New developments in well boring and irrigation in South Dakota," by N. H. Darton; and "Reservoirs for irrigation," by J. D. Schuyler.

1898.

Nineteenth Annual Report of the United States Geological Survey, 1897–98, Part IV, Hydrography, 1899; octavo, 814 pp.

Contains a "Report of progress of stream measurements for the calendar year 1897," by F. H. Newell and others; "The rock waters of Ohio," by Edward Orton; and "Preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian," by N. H. Darton.

1899.

Twentieth Annual Report of the United States Geological Survey, 1898–99, Part IV, Hydrography, 1900; octavo, —— pp.

Contains a "Report of progress of stream measurements for the calendar year 1898," by F. H. Newell, and "Hydrography of Nicaragua," by A. P. Davis.

WATER-SUPPLY AND IRRIGATION PAPERS, 1896–1899.

This series of papers is designed to present in pamphlet form the results of stream measurements and of special investigations. A list of these, with other information, is given on the outside (or fourth) page of this cover.

Survey bulletins can be obtained only by prepayment of cost, as noted above. Postage stamps, checks, and drafts can not be accepted. Money should be transmitted by postal money order or express order, made payable to the Director of the United States Geological Survey. Correspondence relating to the publications of the Survey should be addressed to **The Director, United States Geological Survey, Washington, D. C.**

WATER-SUPPLY AND IRRIGATION PAPERS.

1. Pumping water for irrigation, by Herbert M. Wilson, 1896.
2. Irrigation near Phoenix, Arizona, by Arthur P. Davis, 1897.
3. Sewage irrigation, by George W. Rafter, 1897.
4. A reconnoissance in southeastern Washington, by Israel C. Russell, 1897.
5. Irrigation practice on the Great Plains, by E. B. Cowgill, 1897.
6. Underground waters of southwestern Kansas, by Erasmus Haworth, 1897.
7. Seepage waters of northern Utah, by Samuel Fortier, 1897.
8. Windmills for irrigation, by E. C. Murphy, 1897.
9. Irrigation near Greeley, Colorado, by David Boyd, 1897.
10. Irrigation in Mesilla Valley, New Mexico, by F. C. Barker, 1897.
11. River heights for 1896, by Arthur P. Davis, 1897.
12. Water resources of southeastern Nebraska, by Nelson Horatio Darton, 1898.
13. Irrigation systems in Texas, by W. F. Hutson, 1898.
14. New tests of pumps and water lifts used in irrigation, by O. P. Hood, 1898.
15. Operations at river stations, 1897, Part I, 1898.
16. Operations at river stations, 1897, Part II, 1898.
17. Irrigation near Bakersfield, California, by C. E. Grunsky, 1898.
18. Irrigation near Fresno, California, by C. E. Grunsky, 1898.
19. Irrigation near Merced, California, by C. E. Grunsky, 1899.
20. Experiments with windmills, by Thomas O. Perry, 1899.
21. Wells of northern Indiana, by Frank Leverett, 1899.
22. Sewage irrigation, Part II, by George W. Rafter, 1899.
23. Water-right problems of Bighorn Mountains, by Elwood Mead, 1899.
24. Water resources of the State of New York, Part I, by George W. Rafter, 1899.
25. Water resources of the State of New York, Part II, by George W. Rafter, 1899.
26. Wells of Southern Indiana (continuation of No. 21), by Frank Leverett, 1899.
27. Operations at river stations, 1898, Part I, 1899.
28. Operations at river stations, 1898, Part II, 1899.
29. Wells and windmills in Nebraska, by Erwin Hinckley Barbour, 1899.
30. Water resources of the Lower Peninsula of Michigan, by A. C. Lane, 1899.
31. Lower Michigan mineral waters, by Alfred C. Lane, 1899.
32. Water resources of Puerto Rico, by Herbert M. Wilson, 1899.

In addition to the above, there are, in various stages of preparation, other papers relating to the measurement of streams, the storage of water, the amount available from underground sources, the efficiency of windmills, the cost of pumping, and other details relating to the methods of utilizing the water resources of the country. Provision has been made for printing these by the following clause in the sundry civil act making appropriations for the year 1896–97:

Provided, That hereafter the reports of the Geological Survey in relation to the gaging of streams and to the methods of utilizing the water resources may be printed in octavo form, not to exceed 100 pages in length and 5,000 copies in number; 1,000 copies of which shall be for the official use of the Geological Survey, 1,500 copies shall be delivered to the Senate, and 2,500 copies shall be delivered to the House of Representatives, for distribution. (Approved, June 11, 1896; Stat. L., vol. 29, p. 453.)

The maximum number of copies available for the use of the Geological Survey is 1,000. This quantity falls far short of the demand, so that it is impossible to supply all requests. Attempts are made to send these pamphlets to persons who have rendered assistance in their preparation through replies to schedules or who have furnished data. Requests made for a certain paper and stating a reason for asking for it are granted whenever practicable, but it is impossible to comply with general demands, such as to have all of the series sent indiscriminately.

Application for these papers should be made either to members of Congress or to

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C.

DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 33

STORAGE OF WATER ON GILA RIVER, ARIZONA.—LIPPINCOTT

WASHINGTON
GOVERNMENT PRINTING OFFICE
1900

IRRIGATION REPORTS.

The following list contains titles and brief descriptions of the principal reports relating to water supply and irrigation, prepared by the United States Geological Survey since 1890:

1890.

First Annual Report of the United States Irrigation Survey, 1890; octavo, 123 pp.

Printed as Part II, Irrigation, of the Tenth Annual Report of the United States Geological Survey, 1888–89. Contains a statement of the origin of the Irrigation Survey, a preliminary report on the organization and prosecution of the survey of the arid lands for purposes of irrigation, and report of work done during 1890.

1891.

Second Annual Report of the United States Irrigation Survey, 1891; octavo, 335 pp.

Published as Part II, Irrigation, of the Eleventh Annual Report of the United States Geological Survey, 1889-90. Contains a description of the hydrography of the arid region and of the engineering operations carried on by the Irrigation Survey during 1890; also the statement of the Director of the Survey to the House Committee on Irrigation, and other papers, including a bibliography of irrigation literature. Illustrated by 29 plates and 4 figures.

Third Annual Report of the United States Irrigation Survey, 1891; octavo, 576 pp.

Printed as Part II of the Twelfth Annual Report of the United States Geological Survey, 1890-91. Contains "Report upon the location and survey of reservoir sites during the fiscal year ended June 30, 1891," by A. H. Thompson; "Hydrography of the arid regions," by F. H. Newell; "Irrigation in India," by Herbert M. Wilson. Illustrated by 33 plates and 100 figures.

Bulletins of the Eleventh Census of the United States upon irrigation, prepared by F. H. Newell; quarto.

No. 35, Irrigation in Arizona; No. 60, Irrigation in New Mexico; No. 85, Irrigation in Utah; No. 107, Irrigation in Wyoming; No. 153, Irrigation in Montana; No. 157, Irrigation in Idaho; No. 163, Irrigation in Nevada; No. 178, Irrigation in Oregon; No. 193, Artesian wells for irrigation; No. 198, Irrigation in Washington.

1892.

Irrigation of western United States, by F. H. Newell; extra census bulletin No. 23, September 9, 1892; quarto, 22 pp.

Contains tabulations showing the total number, average size, etc., of irrigated holdings, the total area and average size of irrigated farms in the subhumid regions, the percentage of number of farms irrigated, character of crops, value of irrigated lands, the average cost of irrigation, the investment and profits, together with a résumé of the water supply and a description of irrigation by artesian wells. Illustrated by colored maps, showing the location and relative extent of the irrigated areas.

1893.

Thirteenth Annual Report of the United States Geological Survey, 1891–92, Part III, Irrigation, 1893; octavo, 486 pp.

Consists of three papers: "Water supply for irrigation," by F. H. Newell; "American irrigation engineering" and "Engineering results of the Irrigation Survey," by Herbert M. Wilson; "Construction of topographic maps and selection and survey of reservoir sites," by A. H. Thompson. Illustrated by 77 plates and 152 figures.

A geological reconnaissance in central Washington, by Israel Cook Russell, 1893; octavo, 108 pp., 15 plates. Bulletin No. 108 of the United States Geological Survey; price, 15 cents.

Contains a description of the examination of the geologic structure in and adjacent to the drainage basin of Yakima River and the great plains of the Columbia to the east of this area, with special reference to the occurrence of artesian waters.

1894.

Report on agriculture by irrigation in the western part of the United States at the Eleventh Census, 1890, by F. H. Newell, 1894; quarto, 283 pp.

Consists of a general description of the condition of irrigation in the United States, the area irrigated, cost of works, their value and profits; also describes the water supply, the value of water, of artesian wells, reservoirs, and other details; then takes up each State and Territory in order, giving a general description of the condition of agriculture by irrigation, and discusses the physical conditions and local peculiarities in each county.

Fourteenth Annual Report of the United States Geological Survey, 1892-93, in two parts; Part II, Accompanying papers, 1894; octavo, 597 pp.

Contains papers on "Potable waters of the eastern United States," by W J McGee; "Natural mineral waters of the United States," by A. C. Peale; "Results of stream measurements," by F. H. Newell. Illustrated by maps and diagrams.

(Continued on third page of cover.)

DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

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UNITED STATES GEOLOGICAL SURVEY

No. 33

WASHINGTON
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UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

STORAGE OF WATER

ON

GILA RIVER, ARIZONA

BY

JOSEPH BARLOW LIPPINCOTT

WASHINGTON
GOVERNMENT PRINTING OFFICE
1900

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, December 1, 1899.

SIR: I have the honor to transmit herewith a manuscript prepared by Mr. J. B. Lippincott, giving the results of surveys of reservoirs on Gila River, Arizona, and to recommend that it be printed in the series of Water-Supply and Irrigation Papers.

The investigations upon which this report is based were originally intrusted to Mr. Arthur P. Davis, as he was familiar with the conditions through a preliminary survey. Before the field work was completed, however, his services were required by the Nicaragua Canal Commission, to extend the studies of the water supply of Central America. The responsible oversight was then intrusted to Mr. J. B. Lippincott, who up to that time had been assisting Mr. Davis.

This report has been written by Mr. Lippincott, and his conclusions have been verified by Mr. James D. Schuyler. The latter has prepared a concise discussion of the matter, but at this time it is necessary only to quote his general conclusions and recommendations, as follows:

(1) That a minimum of 40,000 acre-feet of water annually should be stored for the supply of the Indian reservation.

(2) That it is not feasible to obtain this supply from Queen Creek, although the construction of the dam and reservoir proposed on the stream is feasible if a sufficient water supply were available.

(3) That the Gila River is the only available source of permanent supply.

(4) That it is not feasible or advisable to build a dam and reservoir on the Gila for storing so small a quantity as 40,000 acre-feet, on account of the rapidity with which a small reservoir must be filled with silt.

(5) That it is not feasible to construct a reservoir outside of the immediate channel of the Gila River of sufficient capacity to provide for the wants of the Indians, filling the same annually by a conduit from the river.

(6) That it is not advisable to build a dam and reservoir on the channel of the river of less capacity than one-half the total annual flow of the river in minimum years.

(7) That feasible reservoir and dam sites exist on the Gila at the Buttes, Riverside, and San Carlos.

(8) That it is not feasible to build a masonry dam at the Buttes, on account of the rotten quality of the rock, the great depth to bed rock, and the excessive height of dam required to obtain a storage of 174,000 acre-feet, or about one-half the minimum flow of the stream.

(9) That the construction of a combination rock-fill and masonry dam is feasible at the Buttes at a cost of $3,643,827, storing 174,040 acre-feet, but that it is not feasible to construct a dam of any type of greater height or capacity.

(10) That the Buttes reservoir of the stated capacity may be expected to fill with solid matter in eighteen years, unless dredged or sluiced out.

(11) That it is feasible to construct a masonry dam at Riverside at a cost of $1,989,605, including damages for right of way and diversion dam at the head of the Florence canal, forming a reservoir with a capacity of 231,134 acre-feet.

(12) That it is feasible to increase the height of dam at the Riverside dam at least 70 feet higher than the one estimated upon, giving an ultimate reservoir capacity of about 650,000 acre-feet, which would not be filled with solid matter short of sixty-seven years.

(13) That it is feasible to construct a masonry dam at San Carlos at a cost of $1,038,926, including damages for right of way and diversion dam at the head of the Florence canal, forming a reservoir of 241,396 acre-feet capacity, and that the water supply is ample to fill such a reservoir in the years of minimum flow, and that the volume of storage will irrigate at least 100,000 acres in addition to the irrigation of the lands of the Indians.

(14) That it is feasible to construct a dam at San Carlos at least 70 feet higher than that contemplated in the estimates, forming a reservoir whose ultimate capacity would be approximately 550,000 acre-feet and whose probable life of usefulness would be sixty-three years before being filled with silt.

(15) That provision should be made in the working plans for these ultimate extensions suggested and the right of way reserved in the reservoir basin for the additional area that may ultimately be flooded.

(16) That the San Carlos dam should be built as the first step to be taken for the storage of water upon the Gila and that all other available sites should be permanently withdrawn from entry with a view to their ultimate utilization for storage purposes.

(17) That the working plans for the San Carlos dam should be drawn to permit of the complete utilization of all power which may be developed from the head of the water issuing from the reservoir and steps be taken for realizing upon the full commercial value of the power.

(18) That that portion of the public domain which can be irrigated and reclaimed from the surplus storage of the Gila River reservoirs, over and above what is required for the Sacaton Indian Reservation, should be withdrawn from entry, segregated into an irrigation district, provided with a system of canals of distribution, and only offered for sale at a rate commensurate with their true value as irrigable lands with water rights, the proceeds to be placed in a fund to be used only for continuing the improvement, extension, and care of reservoirs and storage dams on the Gila River.

In addition to the investigation authorized by the act of July 1, 1898, related work was carried on at the same time under the annual appropriation for measuring the streams and determining the water supply, thus furnishing general information which has been embodied in the following pages. No attempt has been made in this paper to discriminate between the data acquired by the two classes of field work.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

DRIVING PIPE IN BED OF GILA RIVER AT THE BUTTES, ARIZONA, FOR DIAMOND CORE DRILL

STORAGE OF WATER ON GILA RIVER, ARIZONA.

By JOSEPH BARLOW LIPPINCOTT.

EXISTING CONDITIONS.

LOCATION OF RESERVATION.

The Gila River Indian Reservation consists of a tract of 357,120 acres lying on both sides of Gila River, in southern Arizona. It extends from a point about 9 miles west of Florence to the mouth of Salt River, the principal tributary of the Gila, and is approximately 12 miles south of Phenix, the capital of the Territory. The greater portion of this reservation consists of land whose gentle slopes are well adapted to irrigation. From June 1 to October 1 the weather is exceedingly warm. The relative humidity of the locality, however, is low, so that the effect of the heat is largely mitigated, and prostrations from this cause are rare. It is probably as well suited to occupation from a climatic standpoint as the great valleys of central California or the southern Atlantic coast. The winter season is delightful, the temperature seldom falling lower than 20° F.

The lands of this reservation are arid, the annual rainfall being between 7 and 9 inches, a large portion of the precipitation occurring during the winter or nongrowing months. The growth of all crops in this district is wholly dependent upon irrigation, but with water they can be raised in continuous rotation, while successful dry farming is an impossibility. What is true of the Indian reservation also applies to the adjacent lands of the Gila River Valley. Wheat, barley, corn, and alfalfa grow luxuriantly when watered. The deciduous fruits flourish, but winter temperatures are too low for the citrus species.

DESCRIPTION OF TRIBES.

The Gila River Indian Reservation is occupied chiefly by the Pima and Maricopa Indians and a limited number of Papagos. The first knowledge we have of these Indians is obtained from a narrative of Cabeza de Vaca, a Spanish explorer, who visited this region about the year 1535, after an adventurous journey overland from Florida. This traveler describes them very much as they are to-day. They occupied the same lands as at present, and have evidently long been industrious and successful farmers and irrigators, as they continued to be for many years after the acquisition of Arizona by the United States. Their average wheat crop was about 2,000,000 pounds a year, besides

which corn, pumpkins, beans, sorghum, and vegetables were raised in large quantities. They manufactured ollas, or earthen jars, and baskets and wove very fine blankets and cotton fabrics. They lived in small villages and held their lands in severalty.

The Pimas have always been friends of the whites and enemies of the Apaches. They gave succor and assistance to the early white settlers, and their doors were always open to peaceable whites or Indians when hard pressed by the savage foe. It is their boast that their hands were never stained by the white man's blood. It was under such conditions that they were joined, about a century ago, by the Maricopas, who came as fugitives from the more powerful Yuma tribe. When the belligerent Apaches gave trouble to the settlers, the United States troops sometimes obtained substantial aid and comfort from the Pimas in the way of subsistence.

The agriculture of the Pima Indians was carried on entirely by irrigation with water diverted from Gila River. These tribes have always supported themselves, and their progress toward civilization has been regarded as one of the encouraging features of the Indian problem. During the last ten years, their irrigating water having been taken away from them, they have lapsed into indolence, want, and vice.

DECREASE OF WATER SUPPLY.

Their condition of prosperity, industry, and independence continued until, by the settlement of the Gila Valley above the reservation, the water supply was partly cut off and began to be deficient for the cultivated lands on the reservation. No very serious shortage occurred, however, until after the construction of the Florence canal and its diversion dam, heading about 15 miles above the eastern limit of the reservation on Gila River. When this canal was projected, early in the year 1886, Agent Wheeler called the attention of the Department of the Interior to the fact that if the construction of this canal were permitted, it "would practically destroy the farms of the Pima and Maricopa Indians living on the river," and that the effect would be to render the Indians helpless and destitute, the water being absolutely necessary to their existence. On March 2, 1886, the subject was referred by the Department to the Attorney-General, who directed the United States district attorney for Arizona to take the necessary steps to protect the Indians from the effects of the projected canal. The matter was delayed until July of the same year, when the Director of the Geological Survey was instructed by the Secretary of the Interior to investigate and report to the Department the effect which the proposed canal would be likely to have upon the water supply for the Indian reservation. As a result of the investigation the following facts were established:

(1) That the water supply of the Pima and Maricopa reservations under present conditions is no more than sufficient for the wants of the Indians.

(2) That the construction of a dam by the Florence Canal Company of the character represented in the correspondence will give the control substantially of all the water of the Gila River; and if the owners of the dam carry the water right also, they can deliver the water to the reservation or not, as best suits their plans.

(3) That the lands outside the reservation which could be economically supplied with water by such a canal greatly exceed in area the amount that the river is capable of supplying, and that the company, with the water rights established, would own the water, with a demand far exceeding the supply, and the Government would have to approach them as a competitor in the market to obtain a supply for the Indians of the reservation.

(4) That if the water supply from the river be shut off, the Indian reservation would become uninhabitable.

(5) If the dam and canal should be constructed, the present and immediate prospective needs of the reservation might be supplied therefrom, and there would be some surplus water to be used for irrigating lands outside the reservation.

(6) That if the agriculture of the Indians residing on the reservation is to have normal growth, and it be the intention to settle other Indians of the neighborhood who are not supplied with agricultural lands on the reservation, the greater part, and perhaps the whole, of the waters of the Gila will be necessary therefor.

As a result of this report the Department of Justice was again requested to take such steps as would be necessary to prevent the diversion of waters of Gila River to the injury of the Indians of the Pima and Maricopa reservations. Some offers of compromise were made by the canal company, and legal steps were held in abeyance until the canal was constructed, and no successful attempt was ever made to prevent the diversion of the river by the Florence canal or to compel such diverters to supply the Indians with water for irrigation, and the matter was finally allowed to drop by the Department of Justice. The result of the diversion was to deprive the Indians of the greater portion of their water supply during the period when the water was most needed to mature their crops. The shortage has been greater some years than others, depending to a certain extent upon the season, whether abnormally dry or otherwise, but in general there has been a progressive decrease of the water supply for the reservation, due originally, in great measure, to the diversion by the Florence canal.

Recent events have, however, altered the aspect of the question, from the fact that the supply for the Florence canal itself is now short, owing to the diversion for irrigation far above that point, chiefly in Graham and Cochise counties, Arizona. The solution of the problem has become more difficult by reason of its postponement and the condition of the Indians more deplorable. Year after year they plowed and sowed and irrigated their crops, only to have them destroyed by drought before maturity by lack of sufficient irrigation water in the drier months. Naturally they have become discouraged by these fruitless efforts, and great demoralization has resulted. A few who are favorably located at points where water appears in the dry bed of the Gila can still mature their crops; a few others are able to eke out an existence by hauling wood or other precarious employments, while

the larger number have become more or less dependent upon charity or have degenerated into thieves and vagabonds.

NECESSITY FOR RELIEF.

On March 27, 1895, Mr. J. Roe Young, United States Indian agent at Sacaton, made a terse statement of the case to the Indian Bureau, closing his letter with the following recommendation:

What is best to be done I do not know. I recommend, however, that a competent, thorough, and skillful engineer, well acquainted with irrigation questions, be employed to ascertain and report, first, whether or not under existing conditions a supply of water adequate to the needs of these Indians can be obtained and retained permanently, and then, if such a supply can be obtained, what is the best, most feasible, practicable, and economical method of doing so. To properly do this the engineer should examine carefully the past and present condition and flow of the Gila River, the amount of water which formerly passed through this reservation, and the amount we are now receiving; the number and amount of inches of water for which charters for ditches have been granted in the different counties through which the Gila flows, and the amount of water taken out under these charters, together with the number of such charters now legally in force; the underground currents and rock strata along the river, and all matters which, taken together, may lead to some solution of this question. I have been unable to get an estimate of what amount such an investigation and report will cost, but I would suggest that the sum of $5,000 be set apart from any appropriation available for this purpose. Competent and first-class engineers, with ability to make such a report as this case requires, are scarce and high-priced, and they have to be well paid. It would be money thrown away to employ a man not thoroughly posted.

This matter should be taken up soon, in order that we may know what to expect for next year.

Mr. Elwood Hadley, who is now (1899) the Indian agent at Sacaton, in describing the present condition of the Indians of the Gila River Reservation, writes as follows, under date of September 25, 1899:

Approximately 6,000 Indians—Pimas, Papagos, and Maricopas—are dependent for their subsistence upon the lands of the Gila River Reservation, which reservation contains 357,120 acres. It is estimated that half of the land could be made productive with water to irrigate it. The water supply in the Gila River the present season, owing to its use for lands above us, has not been sufficient to irrigate 1,000 acres. Fully half the crops planted have not produced enough for seed. This land is very fertile. The condition of affairs here shows that in the past three years there has been a large falling off in the water supply for irrigation. The reason is apparent in the absorption of the water by additional cultivated lands above.

I notice in the Indians a restlessness as they realize their helpless condition, and and am often confronted with the solicitous queries, What are we to do? If we plant what we have, what assurance have we of getting it back? Under favorable conditions these Indians, being agricultural and pastoral, would soon become independent, prosperous, civilized citizens. Otherwise, discouragement, hunger, and destitution are their lot. A nomadic life being taken on, their old tribal nature asserts itself, and the expenditures hitherto made and being made by the Government for their education and improvement prove a curse to them rather than a blessing.

It is now necessary to issue considerable subsistence to the Indians whose crops

have been a failure, and this aid will have to be largely increased under the existing limited water supply. A supply of water would permit of the Pima boarding school establishing a model farm, greatly reducing the cost of maintaining the school of 200 pupils, and be a most valuable educational factor in the school life of the pupils. The available Indian labor in the construction of the reservoir is an important factor, as it is much better to provide them labor with pay than keep them as paupers. These Indians are willing to work, and their moral status is good. Their attitude toward the United States has always been friendly. They have saved the Government in protecting the early settlers from the ravages of the Apaches. They have kept themselves within the bounds of law and order, and they are now left upon the desert without water. Humanity speaks, economical administration for the sustenance of the Indians speaks, and Nature, in her wise provisions, says, "Let man's means and intelligence be made operative, that these Indians, whose claims are meritorious, be reinstated in self-sustenance and lifted to the plane of prosperous American citizens."

INVESTIGATION IN 1896.

In November, 1895, the Secretary of the Interior instructed the Director of the Geological Survey to detail a civil engineer to make the examination recommended, and Mr. Arthur P. Davis, hydrographer, was accordingly assigned to this task, in which he was assisted by Mr. Cyrus C. Babb, assistant hydrographer, and Mr. J. B. Lippincott, resident hydrographer for California. Six months of time and $3,500 were expended in the field on the preliminary investigation, and a report was submitted in 1896,[1] entitled The Report on Irrigation Investigation for the Benefit of the Pima and Other Indians on the Gila River Indian Reservation, Arizona.

It was proposed to construct a dam of masonry to the height of 170 feet above the bed of the river, at which height natural facilities occur for the discharge of surplus waters through adequate spillways. This would afford a storage of about 200,000 acre-feet of water below the flow line of 160 feet above the bed of the river. The provisional estimate of the cost of this project aggregated $2,244,000. The great uncertainty attaching to this project was the location of bed rock at a great but unknown depth. Numerous reports were obtained of soundings varying from 40 to 50 feet in depth without striking bed rock.

Inquiry showed that it would be impossible to obtain suitable drilling machinery for a thorough exploration of the foundation, and as a preliminary makeshift the method of sounding by driving rods was resorted to. Rods were driven in eleven places, at intervals of 40 feet, in the proposed dam site, eight of the soundings being 50 feet or more and one reaching the depth of 65 feet. It was impossible with the means at hand to determine whether or not the rods had reached bed rock, but the preliminary estimates were made on the hypothesis that the depth of rock was 65 feet, and in the report of the work it was recommended that "thorough exploration should be made with a core drill before beginning of construction of the dam."

[1] Senate Doc. No. 27, Fifty-fourth Congress, second session.

INVESTIGATION IN 1899.

For the purpose of continuing the investigation along the lines recommended by Mr. Davis a paragraph was inserted in the act making appropriation for current and contingent expenses in the Indian Department, approved July 1, 1898, as follows:

For ascertaining the depth of the bed rock at a place on Gila River, in Gila County, Arizona, known as the Buttes, and particularly described in the Senate Document Number Twenty-seven, Fifty-fourth Congress, second session, and for ascertaining the feasibility and estimating in detail the cost of the construction of a dam across the river at that point for the purpose of irrigating the Sacaton Reservation, and for ascertaining the average daily flow of water in the river at that point, twenty thousand dollars, or so much thereof as may be necessary, the same to be expended by the Director of the United States Geological Survey, under the direction of the Secretary of the Interior: *Provided*, That nothing herein shall be construed as in any way committing the United States to the construction of said dam; and said Director shall also ascertain and report the feasibility and cost of the Queen Creek project mentioned in said Senate document.

In order to carry out the provisions of this act stream measurements were begun on Gila River at the Buttes and on Queen Creek at the site of the proposed dam, in November, 1898, and have been maintained to date (October, 1899). As the site at the Buttes was inaccessible by heavy wagons, a road was built to facilitate the transportation of machinery to the site for drilling. Bids were invited by advertisement for the exploration of bed rock, but were rejected, as it was found that the amount of drilling desirable would, under the most favorable proposal, cost more than the available funds. Two diamond drills, a few diamonds, and two pipe-driving machines were loaned to the Survey for this work by the Nicaragua Canal Commission, and borings were begun at the Buttes in January, 1899.

Twenty-five holes were put down to bed rock at the Buttes with a diamond core drilling apparatus. These holes were distributed up and down the narrow portions of the canyon in order to determine the most acceptable point for the location of the dam. The depths reached were unexpectedly great. This work is described in detail under the account of the diamond core drill borings on page 48. The maximum depth reached by any of the holes was 122.6 feet to bed rock. Because of this great depth an effort was made to find another location for a dam that could utilize the Buttes reservoir site as filed upon under the United States laws. The appearances were favorable for the proximity of bed rock to the surface near the head of the Florence canal, 3½ miles below the Buttes, where the canyon is quite wide, but where outcroppings of rock in places occur. The depth to bed rock at this site—82 feet 2 inches—as determined by borings shown on the map, Pl. VIII, *B*, was too great to justify the location of the dam at this place. The portion of the canyon was contoured between the old reservoir survey, which began at the Buttes dam site proper and the head of the Florence canal, so that a revised capacity of the reservoir could be computed if the dam

should be built at the head of the Florence canal. At a point 4 miles above the Buttes, where a dike of volcanic rock apparently of more recent geological formation than the surrounding country crossed the canyon, another exploration for bed rock was made. The canyon at this point at the base of the cliffs is 459 feet in width. As a hole was put down to a depth of 96.3 feet without finding bed rock at this point, this location was condemned as a dam site without further exploration, particularly in view of the excessive length of dam required.

In order to determine the feasibility of constructing a dam at the Buttes, as compared with other possible locations, the Gila River above this location was explored for reservoir sites, and three were found of ample storage capacity. At Riverside, 12 miles above the Buttes, by the course of the river, an available locality was selected and fourteen holes were sunk, which determined a granite bed rock of good quality to exist at a maximum depth of 75.5 feet. At the San Carlos dam site, the next location above, three holes were put down to determine the depth of bed rock. This was the last dam and reservoir site discovered. The high water then interferred with the work to such an extent that it had to be abandoned in August. The data obtained from these three holes are very meager and should be extended, but they had to be accepted in this estimate as determining bed rock at that point. At the Guthrie reservoir site, which is above Solomonville and uppermost of three available locations examined, a detailed survey was also made. The rock at this dam site consists of a mixed volcanic product, there being strata of gravel deposited between various lava flows. This was considered sufficient in itself to condemn this site for construction purposes. A railroad passes through the length of the reservoir and through the dam site, and a change in its location would be a matter of difficulty and large expense.

The upper portion of Gila River and its principal tributaries were explored by Mr. Cyrus C. Babb, hydrographer, as well as the basin of San Pedro River. In both the Gila and San Pedro basins measurements of all canals were made in order to determine the amount of water returning to the river from irrigation and for purposes of general information. This return water has a particular bearing upon our project as contemplated in that the irrigation of 120,000 acres of land in the neighborhood of Florence and Sacaton may be expected to increase the flow of the lower portion of Gila River in a way similar to that of the cases investigated where irrigation has been practiced for a term of years. In other words, if 50 per cent of the water used for irrigation around Solomonville, on the upper portion of the river, returns to the river below the places where it is used for irrigation, and it may again be used for like purpose below, a similar action may be expected below the irrigated lands which are supplied from this proposed reservoir system. Measurements of return water, or "seepage measurements," were also made in the vicinity of Phenix, which show similar conditions.

The canyon of the Gila, between the mouth of the San Pedro and the San Carlos dam site, was explored and found to be 31 miles in length. It is a narrow gorge, as shown on Pl. II, being thus an excellent conduit for the passing of the liberated water from the San Carlos dam site to the irrigable lands below. A traverse survey was made throughout its length. Observations for determining the average evaporation, the range of temperature, and the volumes of suspended silt in the river have been maintained at the Buttes during the period of the survey. A canal line has been surveyed from the Buttes dam site past the head of the Florence canal, a distance of 4 miles. This canal would be used in connection with the Buttes reservoir site for the purpose of delivering its water to the irrigable lands, and largely for the development of power, which could be used, if desired, in the settlements that would spring up under this system.

Owing to the questionable character of the rock for building at the Buttes dam site, quarry tests were made, as described fully under the description of the Buttes dam. Mr. E. Duryee, chemist and cement expert, of Colton, California, investigated thoroughly the rocks of all the localities in question, in order to determine the feasibility of the manufacture of a natural hydraulic or a Portland cement. His investigation, as shown in detail on later pages, also determined the possibility of using the siliceous rocks of the respective localities for blending with Portland cement in the manufacture of what is known as "sand cement." The extent of public domain in the irrigable districts was determined from the land-office records at Tucson, Arizona.

Mr. J. H. Quinton was engaged to assist in the designing of the dams and other engineering works. He visited all the localities in question and made a careful field examination. Mr. James D. Schuyler was employed for purposes of consultation in the planning of the work, in an advisory capacity, and for this purpose made detailed examinations of the various dam sites on two occasions during the progress of the field investigation. The service which Mr. Schuyler has rendered in this capacity has been of prime importance to the work, owing to his very extended experience in the construction of dams for irrigation purposes.

The general plans for dams at all points have been matters of discussion during a period of months by all the engineers connected with this investigation. Each has contributed his share toward the formation of the final plans which Mr. Quinton has prepared. The office work for the report has been done in Los Angeles, where the plans and estimates have been prepared. Numerous laboratory tests of material from the dams and of the sand cements have been made. Mr. Arthur P. Davis, hydrographer, was in charge of the organization of the field work and of its execution until May 1, 1899, when he was detailed to assist the Nicaragua Canal Commission in its work on the Isthmus. Mr. Davis practically outlined the field work. His ideas with reference to plans of construction have been given most careful

A. GILA RIVER CANYON, 15 MILES BELOW SAN CARLOS DAM SITE.

B. GILA RIVER CANYON, 8 MILES BELOW SAN CARLOS DAM SITE.

consideration in reaching final conclusions, and to him is due the credit, in large part, for the successful carrying out of the work and for its breadth and scope.

AMOUNT OF WATER REQUIRED.

In order to determine the amount of water that will be required for the Indians on the Gila River Indian Reservation, Mr. Elwood Hadley, United States Indian agent at Sacaton, was requested to make a statement on the subject. In his reply, dated October 12, 1899, he writes:

> It is estimated that there are nearly 4,500 Pima and Maricopa Indians on the reservation dependent for their subsistence upon its lands. South of this reservation, in the country lying between the Southern Pacific Railroad and the border line of Mexico, it is estimated that there are nearly 2,000 nomadic Papagos, who derive much of their subsistence from the Pimas of this reservation (Gila River) in exchange for their labor. The Pimas are liberal and kind to their more unfortunate brothers, and give them a share of their products in return for their labor in harvesting the crops.
>
> The estimated number of Indians under my care is as follows: Pimas, 4,200; Maricopas, 350; Papagos, 2,700; total, 7,250.
>
> The number named above who live on reservations away from here would gladly come here if they could be furnished with water. It is estimated that 2 acres of land will sustain an Indian.

The report of the Commissioner of Indian Affairs for 1896 gives for the Pima Agency the following population: Pimas, 4,260; Maricopas, 340; Papagos, 1,224; Papagos, nomadic, 2,046—total, 7,870. This does not state, however, whether these are actually on this particular reservation or on others.

In the report of Mr. Arthur P. Davis, of 1896, it is estimated that 1.5 acres of ground is necessary for the support of each Indian. This estimate is thought to be liberal. In the irrigated districts of southern California an inhabitant to each acre is sustained. For the irrigation of grain probably 1.5 acre-feet of water is sufficient for the complete development of the crop for each season; but for the growth of alfalfa or orchards a lower duty of water will be required, and 2 acre-feet per acre is assumed in this report to be a satisfactory supply. If there are 7,250 Indians now located upon this reservation or deriving their subsistence from it, each requiring 1.5 acres of irrigated land, it would be necessary to supply 10,875 acres with water to meet present demands. At the rate of 2 acre-feet of water for each acre irrigated, it will be necessary to furnish 21,750 acre-feet to the reservation to meet this requirement. There will doubtless be other Indians on neighboring reservations on the lower portion of Gila River, whom the Department would desire to move onto the Gila Reservation in case an abundant supply of water could be furnished to them. In view of these possible transfers, and of the natural increase in numbers of the tribes now dependent upon the reservation, a prospective demand on the reservoir system of 40,000 acre-feet is considered necessary.

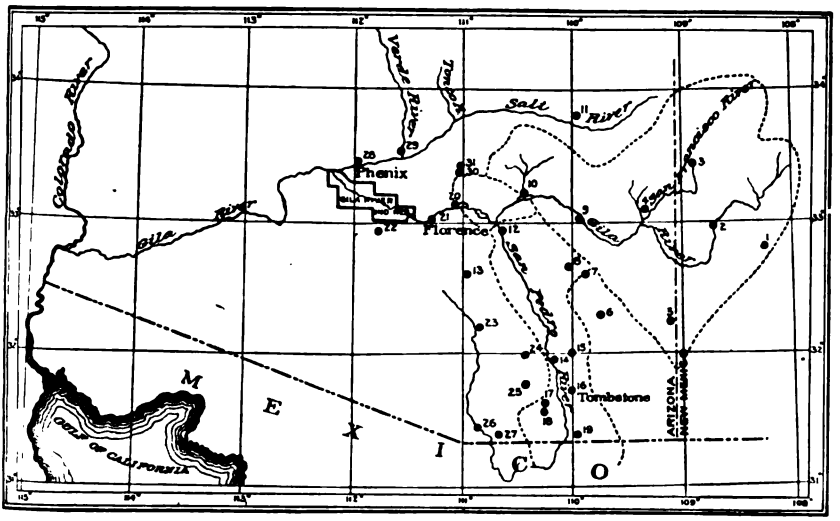
WATER SUPPLY.

PRECIPITATION.

Rainfall observations have been taken at thirty-one different points in the basin of Gila River above the Buttes, as shown on Pl. III, *A*, the earliest record beginning at Fort Bayard, New Mexico, in 1867. Undoubtedly the greatest precipitation of the basin occurs in the higher mountains, in its northeastern portion. The records for these mountain districts are rare, most of them being taken in the valleys where settlements and agriculture occur. It is probable, therefore, that the actual rainfall for the basin is greater than that indicated by the tables and diagrams. For the purpose of this report the rainfall observations in the basin of Gila River above the Buttes have been grouped in three classes in the following table—first, the Gila Basin proper, exclusive of the basin of the San Pedro; second, the basin of the San Pedro; and third, a series of observations at three stations in the vicinity of Florence, five stations in the basin of Santa Cruz River, which stream enters the Gila below the mouth of the Salt, and three sets of observations in the vicinity of Phenix. The segregation of the records into the groups named is for the purpose of comparing the relative amount of water available for storage purposes at the reservoir site at San Carlos and at the Buttes.

Annual rainfall, in inches, in basin of Gila River above San Carlos, Arizona.

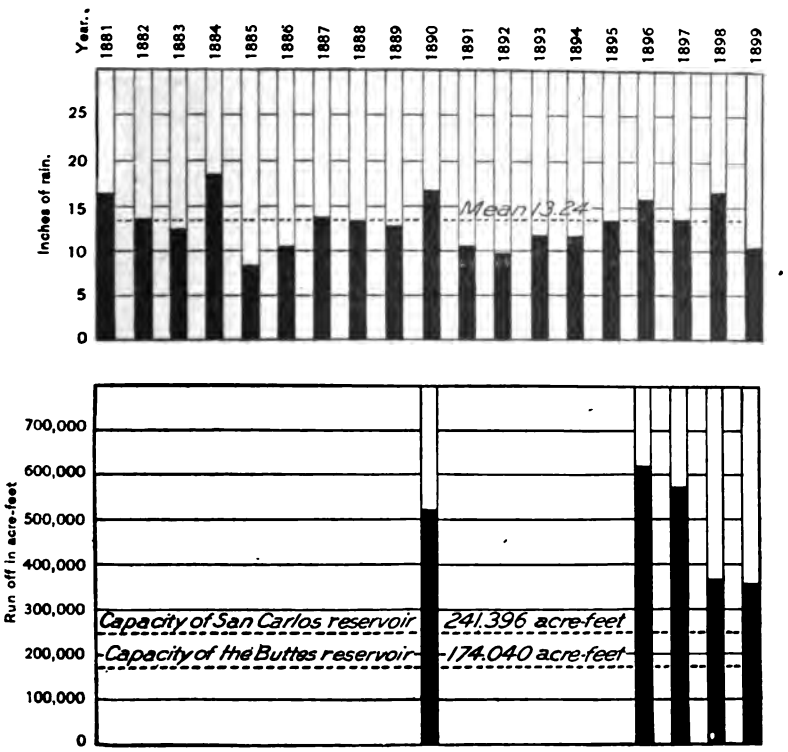
	Fort Bayard.	Gila.	Alma.	Oro.	San Simon.	Willcox.	Fort Grant.	Cedar Springs.	Fort Thomas	San Carlos.	Fort Apache.	Mean above San Carlos.
Elevation (feet)	6,022	.....	5,500	3,610	3,611	4,164	4,860	4,900	2,700	2,450	5,050	.....
Year:												
1867	13.87	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1868	15.23	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1869	12.84	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1870	10.07	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1871	5.79	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1872	13.61	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1873	22.18	.....	.....	.....	.....	.....	17.99	.....	.....	.....	.....	.....
1874	20.38	.....	.....	.....	.....	.....	17.81	.....	.....	.....	.....	.....
1875	19.66	.....	.....	.....	.....	.....	20.91	.....	.....	.....	.....	.....
1876	18.94	.....	.....	.....	.....	.....	.....	.....	.....	.....	19.74	.....
1877	13.12	.....	.....	.....	.....	.....	10.13	.....	.....	.....	12.50	.....
1878	.....	.....	.....	.....	.....	.....	16.46	.....	.....	.....	28.61	.....
1879	.....	.....	.....	.....	.....	.....	12.82	.....	.....	.....	18.58	.....
1880	.....	.....	.....	.....	.....	.....	15.74	.....	.....	.....	14.77	.....
1881	.....	.....	.....	.....	.....	12.11	18.96	.....	11.41	.....	31.12	18.40
1882	.....	.....	.....	.....	6.50	8.58	15.42	.....	8.66	15.27	27.62	13.69
1883	.....	.....	.....	.....	7.15	8.73	15.48	.....	10.85	12.21	21.65	12.68
1884	.....	.....	.....	.....	10.37	14.38	25.67	.....	18.16	20.41	29.47	19.74
1885	.....	.....	.....	.....	2.39	8.51	9.21	.....	8.70	8.19	15.58	8.76
1886	.....	.....	.....	.....	2.02	9.37	.....	.....	10.86	10.44	21.06	10.75
1887	13.59	.....	.....	.....	.99	16.49	24.32	.....	16.35	8.68	17.84	14.04
1888	13.42	.....	.....	.....	4.55	11.93	14.20	.....	13.34	13.04	18.89	12.77
1889	7.21	.....	.....	.....	.....	13.68	13.32	16.44	10.89	13.40	17.10	12.60
1890	.....	.....	.....	15.94	8.43	.....	15.88	.....	13.93	17.86	26.72	16.46
1891	10.30	.....	.....	10.90	4.04	7.36	12.21	.....	.....	11.00	13.36	9.86
1892	8.80	.....	.....	.....	2.57	8.01	7.90	.....	.....	12.05	12.70	8.67
1893	.....	.....	.....	.....	5.65	8.95	13.85	.....	.....	12.53	15.08	10.21
1894	8.67	.....	.....	.....	3.24	5.88	13.53	.....	.....	10.15	17.42	9.81
1895	14.45	12.41	16.51	.....	2.78	8.04	13.22	.....	.....	14.41	16.08	12.48
1896	19.98	17.87	15.09	12.99	4.36	9.22	15.99	.....	.....	13.88	16.09	13.84
1897	17.00	14.44	15.68	10.69	.....	5.66	13.87	.....	.....	7.90	14.98	12.52
1898	16.21	15.22	17.26	16.14	.....	8.16	14.26	.....	.....	7.79	20.55	14.45
1899	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Mean	14.06	14.98	16.13	13.33	4.65	9.42	15.34	.....	12.32	12.31	19.54	12.87



A. LOCATION OF RAINFALL STATIONS IN BASIN OF GILA RIVER.

Rainfall stations:

1. Fort Bayard.
2. Gila.
3. Alma.
4. Oro (Clifton).
5. San Simon.
6. Willcox.
7. Fort Grant.
8. Cedar Springs.
9. Fort Thomas.
10. San Carlos.
11. Fort Apache.
12. Dudleyville.
13. Oracle.
14. Benson.
15. Dragoon.
16. Tombstone.
17. Fort Huachuca.
18. Huachuca Mountains.
19. Bisbee.
20. Buttes.
21. Florence.
22. Casa Grande.
23. Tucson.
24. Pantano.
25. St. Helena Ranch.
26. Calabasas.
27. Lochiel.
28. Phenix.
29. Fort McDowell.
30. Pinal Ranch.
31. Silver King.



B. RAINFALL AND RUN-OFF IN GILA BASIN.

Annual rainfall, in inches, at stations in basin of San Pedro River, Arizona.

	Dudleyville.	Oracle.	Benson.	Dragoon.	Tombstone.	Fort Huachuca.	Huachuca Mountains.	Bisbee.	Mean San Pedro Basin.	Mean above the Buttes.
Elevation (feet)	2,360	4,500	3,580	5,436	.....	5,100	5,000	5,500	.....	.....
Year:										
1881	.....	.....	8.60	.....	.....	.....	.....	.....	.....	16.44
1882	.....	.....	9.64	.....	.....	.....	.....	.....	.....	13.11
1883	.....	.....	10.57	.....	.....	.....	.....	.....	.....	12.88
1884	.....	.....	8.69	.....	.....	.....	.....	.....	.....	18.16
1885	.....	.....	4.24	.....	.....	.....	.....	.....	.....	8.11
1886	.....	.....	6.27	.....	.....	11.47	.....	.....	8.87	10.21
1887	.....	.....	8.19	.....	.....	15.28	.....	.....	11.73	13.53
1888	.....	.....	7.84	.....	.....	19.95	.....	.....	13.89	13.02
1889	.....	.....	7.78	.....	.....	15.39	15.87	.....	13.01	12.73
1890	.....	.....	13.83	.....	.....	19.60	.....	20.22	17.88	16.93
1891	8.59	.....	5.81	17.38	.....	10.84	12.04	14.34	11.50	10.63
1892	10.29	.....	.....	.....	.....	11.50	12.24	12.92	11.74	9.90
1893	8.37	.....	7.71	.....	.....	20.16	16.58	14.79	13.52	11.87
1894	15.12	18.36	4.57	.....	.....	13.95	16.48	.....	13.69	11.58
1895	15.92	14.44	.....	.....	.....	14.15	.....	14.80	14.82	13.26
1896	15.45	19.62	16.78	16.03	.....	21.27	20.39	20.86	18.62	15.93
1897	10.03	14.43	18.60	8.41	13.44	16.68	22.01	17.59	15.15	13.83
1898	14.96	20.89	.....	11.44	13.50	21.82	26.38	25.87	19.26	16.69
1899	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Mean	12.34	17.55	9.21	13.31	13.47	16.31	17.75	17.67	14.13	13.24

Annual rainfall at stations in basin of Gila River, in the vicinity of Florence, Tucson, and Phenix, Arizona.

	Florence vicinity.			Santa Cruz Basin.					Phenix vicinity.			
	Buttes.	Florence.	Casa Grande.	Tucson.	Pantano.	St. Helena ranch.	Calabasas.	Lochiel.	Phenix.	Fort McDowell.	Pinal ranch.	Silver King.
Elevation	1,600	1,498	1,396	2,404	3,538	.....	3,445	5,100	1,068	1,250	4,400	3,800
Year:												
1867	.....	.....	.....	.....	.....	.....	.....	.....	.....	15.26	.....	.....
1868	.....	.....	.....	.....	.....	.....	.....	.....	.....	15.22	.....	.....
1869	.....	.....	.....	.....	.....	.....	.....	.....	.....	7.69	.....	.....
1870	.....	.....	.....	.....	.....	.....	.....	.....	.....	5.45	.....	.....
1871	.....	.....	.....	.....	.....	.....	.....	.....	.....	4.94	.....	.....
1872	.....	.....	.....	.....	.....	.....	.....	.....	.....	20.01	.....	.....
1873	.....	.....	.....	.....	.....	.....	.....	.....	.....	8.13	.....	.....
1874	.....	.....	.....	.....	.....	.....	.....	.....	.....	16.84	.....	.....
1875	.....	.....	.....	.....	.....	.....	.....	.....	.....	4.97	.....	.....
1876	.....	9.33	.....	14.02	.....	.....	.....	.....	.....	7.73	.....	.....
1877	.....	5.35	.....	12.77	.....	.....	.....	.....	5.17	9.38	.....	.....
1878	.....	13.49	.....	16.66	.....	.....	.....	.....	8.52	11.92	.....	.....
1879	.....	12.02	.....	12.01	.....	.....	.....	.....	6.40	8.34	.....	.....
1880	.....	5.35	.....	6.61	.....	.....	.....	.....	6.82	6.61	.....	.....
1881	.....	12.14	1.73	14.92	15.65	.....	.....	.....	8 91	7 24	.....	.....
1882	.....	.....	.....	15.59	15.73	.....	.....	.....	6.94	9.10	.....	.....
1883	.....	.....	3.01	7.78	.....	.....	.....	.....	7.40	9.89	.....	.....
1884	.....	.....	9.71	15.03	.....	.....	.....	.....	12.33	20.95	.....	.....
1885	.....	.....	2.02	5.26	8.96	.....	.....	.....	3.77	8.30	.....	.....
1886	.....	.....	5.12	8.59	10.36	.....	.....	.....	5.78	8.08	.....	.....
1887	.....	.....	7.71	12.95	.....	.....	.....	.....	.....	10.32	.....	.....
1888	.....	.....	4.30	10.60	.....	.....	.....	.....	.....	11.91	.....	.....
1889	.....	8.90	4.25	18.37	15.50	.....	.....	.....	.....	12.78	.....	.....
1890	.....	12.70	10.70	14.16	18.71	.....	.....	26.90	.....	.....	.....	.....
1891	.....	8.24	3.62	7.30	9.87	.....	9.65	15.10	.....	.....	.....	.....
1892	.....	9.95	8.75	9.61	10.79	.....	11.83	.....	5.50	.....	.....	.....
1893	.....	9.63	4.92	13.12	3.35	.....	10.28	.....	7.68	.....	.....	.....
1894	.....	.....	5.82	7.29	18.84	.....	10.29	.....	5.50	.....	.....	.....
1895	.....	.....	.....	11.07	11.40	.....	15.14	.....	.....	.....	.....	.....
1896	.....	.....	.....	11.39	14.58	.....	.....	.....	10.48	.....	20.38	.....
1897	7.59	.....	3.03	10.77	10.73	18.21	10.83	16.14	9.37	.....	23.23	.....
1898	.....	.....	.....	12.72	12.16	.....	.....	.....	5.95	.....	19.84	.....
1899	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Mean	.....	9.74	5.33	11.68	12.62	.....	11.34	19.38	7.35	10.48	21.15	

The records in the vicinity of Florence and Phenix apply to the districts where the water stored will probably be applied for irrigation, and indicate the need of an artificial supply. In the case of the San Pedro Basin, the greater portion of its water supply is furnished near the headwaters of that stream. The lower portion of the river, which constitutes the greater part of its area, being low in elevation, has a relatively lighter rainfall, and, owing to the flat nature of the valleys, a low per cent of run-off. The observations of precipitation in the San Pedro Basin have, with one exception—those of Dudleyville—been made in this upper portion of the basin and at points of high elevation. They indicate, therefore, a water supply in excess of conditions as they really exist.

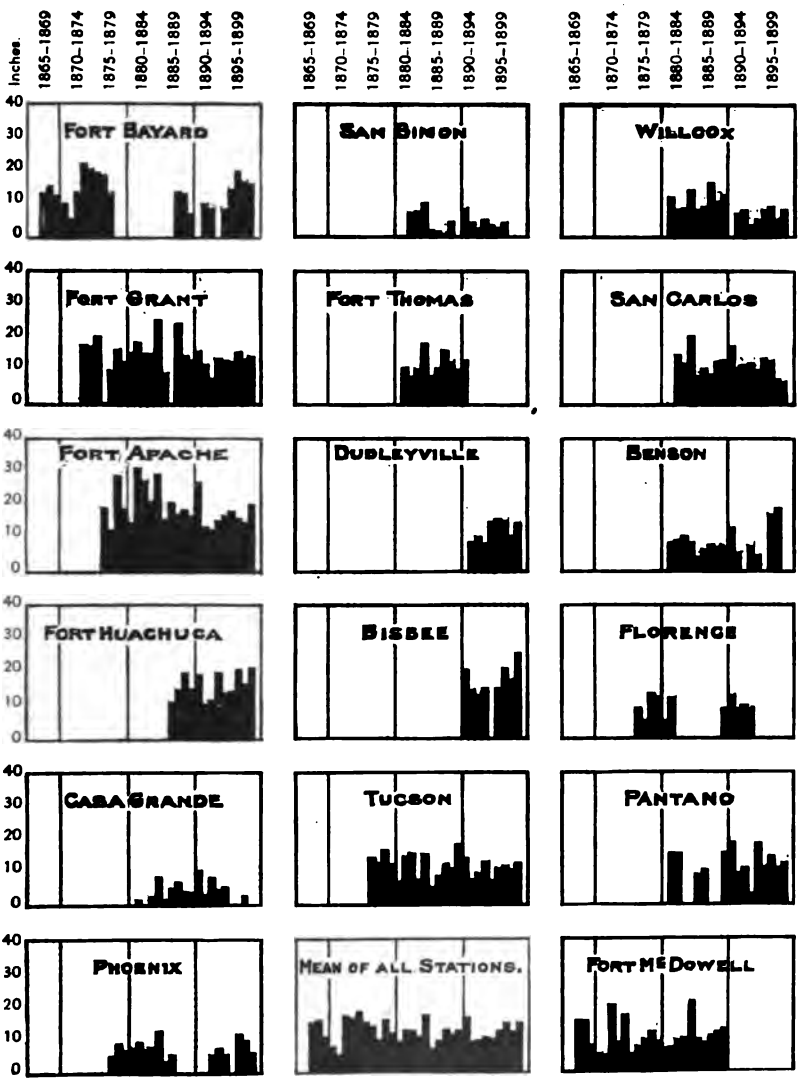
In connection with the study of the increase of rainfall with an increase in elevation, the following table is of interest:

Increase of rainfall with each 100 feet of rise in elevation, with Fort McDowell as a base.

Station.	Length of record.		Elevation.	Elevation above McDowell.	Measured rain.	Constant increase per 100 feet rise.
	Yr.	*mo.*	*Feet.*	*Feet.*	*Inches.*	*Inches.*
McDowell	23	10	1,250	.....	10.38	Base.
Lowell	19	5	2,400	1,150	12.87	0.17
Breckenridge	6	10	3,800	2,550	17.03	.26
Fort Grant	17	2	4,860	3,610	16.85	.18
Fort Buchanan	3	11	5,330	4,080	21.58	.27
Fort Apache	18	10	5,050	3,800	21.04	.28
Verde	22		3,160	1,910	13.13	.15
Prescott	23	11	5,390	4,140	17.06	.16
						1.47
Mean						.21

Comparing the stations given in this table with the record at Fort McDowell, which is a very old one, extending from 1867 to 1888, it is found that in eastern Arizona the rate of increase for each 100 feet of rise in elevation is 0.21 of an inch of rain. It is probable that, notwithstanding the fact that the mean rainfall as measured above San Carlos for all stations is 12.87 inches, and that the mean for the San Pedro Basin is given as 14.13, the average rainfall of the basin of the Gila above San Carlos is greater than the average for the entire San Pedro Basin, and consequently the run-off per square mile of the San Pedro Basin, owing particularly to the flat valley lands through which the river flows in the greater portion of its course, is less than the run-off per square mile of the Gila above San Carlos. This is sustained by observations of flow of both streams during a period of five months.

A diagram is given (Pl. IV) showing the precipitation, in inches per



ANNUAL RAINFALL AT EIGHTEEN STATIONS IN THE BASIN OF GILA RIVER.

annum, during the years when observations of the rainfall were made at various typical stations. For 1899 the figures are estimated after September 1. Data were had from the records of the Signal Service and of the Weather Bureau showing the amount of precipitation each month at each of the eighteen stations named in the table, but they are considered too voluminous for publication. The table of annual rainfall in the basin of the Gila is compiled from this mass of detail. After careful consideration it was deemed impossible to give an average rainfall for the basin based on probable rainfall at various elevations. The means given in the table and diagrams are the direct means of the stations at which observations were made, each being given equal weight in the years when its record occurs. In the case of the upper portion of the Gila the mean has not been extended back of 1881, as sufficient data do not exist upon which to base an accurate deduction. The few points at which observations were taken prior to 1881 would probably indicate a greater rainfall for the basin than existed, owing to their relatively great elevation. In like manner, the record of the San Pedro is not extended back of 1886.

SUBDIVISIONS OF THE DRAINAGE BASIN.

The outlines of the Gila River Basin have been marked on the Land Office maps of Arizona and New Mexico and the areas measured by planimeter. The basin of the southern tributary, the San Pedro, extends into the Republic of Mexico. From the best obtainable data the area in Mexico has been determined to be 120 square miles. The following table classifies the drainage basin of the Gila above the Buttes into three parts: First, the area above the San Carlos dam site, which would be tributary to a reservoir if located at that point; second, the area of the basin of San Pedro River; third, small intermediate basins below San Carlos. The San Pedro Basin is difficult of exact determination, owing to the excessive flatness of the Sulphur Springs Valley, extending from near Camp Grant to the Mexican line and varying from 30 to 40 miles in width. This valley is a great sink from which little or no run-off occurs, and it has been eliminated from consideration in this estimate south of the Graham County line. A small area between San Carlos and the Buttes is directly tributary to Gila River, independently of the San Pedro. The principal stream in this last-named district is Mineral Creek.

Drainage area of Gila River above the Buttes, Arizona.

	Square miles.	
Drainage above San Carlos:		
In Arizona	7,378	
In New Mexico	6,077	
Total		13,455
San Pedro above mouth:		
In Arizona	3,336	
In Mexico	120	
Total		3,456
Small tributaries between San Carlos and the Buttes		923
Total area of Gila Basin above the Buttes		17,834
Total area below San Carlos		4,379

The total accepted area for the basin of Gila River above the Buttes is 17,834 square miles. The total area below San Carlos and above the Buttes is 4,379 square miles, which is practically 25 per cent of the entire area above the Buttes.

RELATIVE FLOW AT SAN CARLOS AND THE BUTTES.

In the Twelfth Annual Report of the Survey, Part II, page 305, is given a tabulation of the observations made on San Pedro River at its mouth, at Dudleyville, Arizona, from May to August, inclusive, 1890. During this period there was discharged from that stream 19,488 acre-feet of water. During the same period of time, as measured at the Buttes below the mouth of San Pedro River, there was a total discharge from the basin of 207,936 acre-feet. This shows that 9.4 per cent of the total discharge of the basin above the Buttes came from the San Pedro, and that 90.6 per cent came from other portions of the stream. There are 923 square miles tributary to the Gila above the Buttes and below San Carlos other than the San Pedro drainage.

From the above figures it is considered fair to estimate that 90 per cent of the water of Gila River comes from above San Carlos and that a reservoir located at the last-named point would only lose 10 per cent of the total amount flowing by the Buttes. Moreover, the amount which enters the stream below San Carlos would not necessarily be entirely lost to a reservoir at that point, as the discharge from the reservoir could be regulated, at least in part, so as to take advantage of the amount of water available from the San Pedro. The synchronous observations which have been made from July 19 to September 23, 1899, at San Carlos and at the Buttes have not yet been of sufficient duration to admit of drawing general conclusions.

During the month of July the record indicated that 91 per cent of the total flow at the Buttes passed San Carlos. During the month of August there was deficient rainfall throughout Arizona in general. According to the statement of the Weather Bureau (report for August, 1899, Arizona section), "The average precipitation for the Territory for the month of August was 85 per cent less than the normal. The average determined from the measurements of 59 stations was 1.26 inches, which is 1.75 inches less than the average for August, 1898. The greatest amount measured at any station during the month was 5.77, at Fort Huachuca, and no precipitation was reported at several stations." Fort Huachuca is in the headwaters of the basin of the San Pedro, and the rainfall at other stations in that neighborhood was abnormally large for August. As might be expected, therefore, during the month of August the discharge from the San Pedro has been proportionately great. The record of stream measurements indicates 60 per cent of the total flow as measured at the Buttes passing San Carlos during August. From September 1 to 23, inclusive,

there was 59 per cent at San Carlos. No rainfall records for September, 1899, are at present (October 3, 1899) available.

The record for the four months given in 1890 indicates 90 per cent of the total flow at the Buttes available at San Carlos, and during the two complete months (July 19 to September 23) when the measurements were maintained in 1899 at both places a mean of 74 per cent was available at San Carlos, or an average for the entire period of six months of 83 per cent at San Carlos.

The following figures are the result of comparative measurements at the Buttes and San Carlos during July, August, and September, 1899:

Comparative discharge of Gila River at San Carlos and the Buttes, in cubic feet per second.

	July.		August.		September.	
	San Carlos.	The Buttes.	San Carlos.	The Buttes.	San Carlos.	The Buttes.
1	.....	.....	780	1,850	80	60
2	.....	.....	3,188	2,850	80	50
3	.....	.....	960	4,100	80	45
4	.....	.....	780	2,260	80	42
5	.....	.....	520	1,040	80	24
6	.....	.....	520	920	230	31
7	.....	.....	590	660	290	1,300
8	.....	.....	460	1,380	7,920	10,187
9	.....	.....	680	905	780	2,923
10	.....	.....	520	717	520	1,950
11	.....	.....	370	460	410	1,382
12	.....	.....	330	515	330	734
13	.....	.....	330	397	290	510
14	.....	.....	260	397	230	399
15	.....	.....	260	280	200	357
16	.....	.....	200	215	200	288
17	.....	.....	200	315	200	249
18	.....	.....	140	210	200	205
19	11,976	1,800	140	270	170	202
20	6,568	8,700	140	175	140	147
21	2,174	4,100	140	135	110	130
22	1,836	2,260	140	100	110	126
23	1,836	1,900	110	112	110	99
24	1,498	1,550	110	90	.....	.....
25	960	1,445	110	89	.....	.....
26	780	1,550	110	80	.....	.....
27	840	1,550	80	80	.....	.....
28	750	3,640	80	70	.....	.....
29	960	2,440	140	71	.....	.....
30	590	2,475	80	60	.....	.....
31	520	995	80	77	.....	.....
Mean	2,407	2,647	405	671	555	932
Per cent	91	.....	60	.....	59	.....

The inspection and study of the basin of the San Pedro, as well as of the Gila proper, by members of this Survey, and the study made of the relative values of their drainage areas, justify the conclusion drawn from all the measurements that 90 per cent of the total flow as measured at the Buttes is available at San Carlos. The larger part of the water of Gila River comes from the San Carlos, the San Francisco, the Blue, and the extreme eastern branches of the stream, and a small per cent enters from the San Simon Plains, which lie between Solomonville and Bowie station on the Southern Pacific Company's railroad.

Wherever irrigation is practiced a certain portion of the water is permanently lost by evaporation from the surface of the ground or from the leaves of the growing plants. Another portion of the water used for irrigation, varying in amount from 20 to 50 per cent, depending upon the nature of the soil and the slopes of the irrigated lands toward the drainage lines, sinks into the ground. This is known as seepage or return water. It fills the pores in the soil, gradually raising the water plane until it flows into natural drainage lines and becomes again available for irrigation. In the Solomonville Valley, in the Gila River Narrows, below the Sanchez ditch, there was, on April 15, 1899, 237 second-feet of water. Within a distance of 40.7 miles below this point there was diverted in ditches 429.8 second-feet of water. A small amount of water is wasted back into the river from these ditches, but the actual amount used for irrigation is 64 per cent in excess of the amount available for that purpose at the highest point of diversion. In other words, an amount equal to 64 per cent of the water found at the head works on April 15, 1899, found its way through underground courses back into the river.

In the valley of the Salt River, near Phenix, there was 40 per cent more water used for irrigation in June, 1899, than was flowing in the river at the highest point of diversion at the head works of the Arizona Canal. It must be remembered in this connection, however, that during the months of July and August there is a much larger volume of water diverted for irrigation than on the dates when these measurements were made, and that a larger amount of water is used on other occasions for the irrigation of these lands than is indicated in this report.

In order to determine the actual ratio between the return water and the amount applied to irrigation the average annual quantity used for irrigation for a term of years should be determined. This amount is at present unknown. It is, however, fair to assume that a substantial percentage of all water used for irrigation finds its way back into the channel of the two streams named above. This may be as high as 25 per cent, as it is known to be greater in other localities. Because of the exceedingly slow movement through soil the discharge is regulated and is of a constant nature. For instance, the flow of Los Angeles River, in California, which receives its water supply from the sand and gravel beds of the San Fernando Valley, which underground reservoir is charged with intermittent floods, has not varied in amount during the last three years to exceed 15 per cent.

It may be confidently expected that as a result of the irrigation of 120,000 acres of lands in the Gila River Valley between Florence and Sacaton 20 or 25 per cent of the water used in this irrigation will return to the channel of Gila River and will be available for further use at lower points on this stream. This would be sufficient to irri-

A. BUTTES DAM SITE, LOOKING UPSTREAM; PROPOSED QUARRIES ON LEFT; SPILLWAY ON LEFT OF CENTER OF FIELD

B BUTTES DAM SITE, LOOKING UPSTREAM FROM UPPER TOE.

gate from 24,000 to 30,000 acres of land, in addition to the areas estimated as capable of being served from a reservoir on Gila River.

MEASUREMENTS OF GILA RIVER AT THE BUTTES, ARIZONA.

Gila River leaves the mountains and enters the plains at a point 15 miles above Florence, known as the Buttes. At this place the river is in a canyon, which is approximately 450 feet wide, its bed being covered with sand and gravel to a maximum depth of 123 feet. Beyond this point, until it forms a junction with its principal tributary, Salt River, it loses in volume. A gaging station was established here and the amount of water available from the basin was accurately determined by the Geological Survey from August 26, 1889, to August 31, 1890, but the work was stopped at the end of this time by lack of available funds. The results of these measurements are given in the Twelfth Annual Report, Part II, Irrigation, pages 306 to 309, and following tables, and are shown graphically on Pl. VI, *B*. A gap occurs in the record from August, 1890, to August, 1895. In the fall of 1895 measurements were begun by the reestablishment of a station at the Buttes above Florence, at the same point that observations were made during the years 1889 and 1890.

From August 1, 1895, to December 10, 1895, gage heights and depths were observed by W. Richins, and occasional estimates of velocity were made, and with these data and the measurements made subsequent to the middle of December the daily discharge for the months of August, September, and November, and the early part of December, 1895, has been ascertained. These results can be regarded only in the light of approximations and do not compare in value with those following December 10. Measurements were continued throughout the year 1896 by W. J. Brash, daily readings of the gage being taken and current-meter measurements made from one to three times a week. The data obtained for the period following December 10, 1895, and extending to October, 1896, are of a high degree of accuracy.

During the year 1897 measurements were continued at this station by W. J. Brash and Albert T. Colton, forty-nine measurements of discharge being taken, the last measurement being made on October 24, 1897. Mr. Brash, who was connected with this work in 1896 and 1897, died in the fall of 1897, and no other person residing in that immediate locality, it was not possible, with funds available, to have the gage rod read daily.

Measurements were made between March 7 and October 10, 1898, by Albert T. Colton, and subsequent to November 14 by Cyrus C. Babb and others connected with the present investigation. Sixteen meter measurements of discharge were thus made, as shown by the diagram, Pl. VI, *B*, prior to November 25, 1898. After this time a contin-

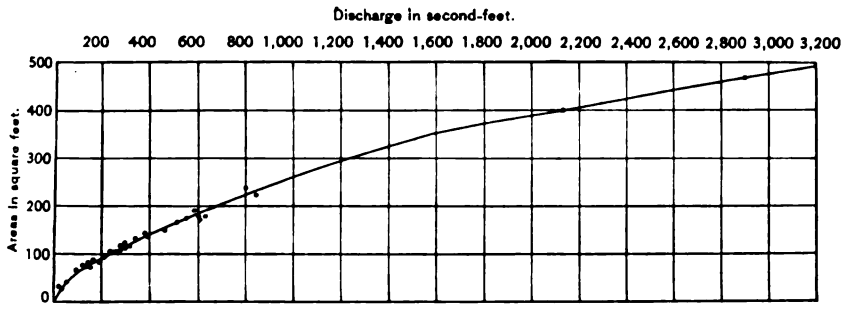
uous record was maintained to the end of the year. In order to make the best possible use of the sixteen observations made prior to November 25, 1898, the volumes as measured on those dates were plotted in diagram, the vertical axis representing volumes measured in cubic feet per second and the horizontal axis representing intervals of one day's time each. The points thus determined were connected by straight lines, and from this diagram monthly estimates of discharge were made. Subsequent to November 25, 1898, daily observations of gage height and area were taken and frequent meter measurements of volume made. As daily measurements of areas in square feet were made, the rating curve graphically shown on Pl. VI, *A*, is in terms of areas of cross section and discharge.

During the year 1899, until October 20, measurements of area were made daily and frequent observations of velocity were taken with a meter. The results are shown graphically on Pl. VI, *B*. The rating table applying from November 25, 1898, to July 10, 1899, is used for the first portion of this year. The meter which was in service at the Buttes got out of order July 20, 1899, and until August 10 observations of gage height and area were taken daily. The discharge during this interval has been computed by using values corresponding to the gage heights determined from the rating curve shown on Pl. VIII, *A*. This exhibits the relation between gage height and discharge, and also, by the position of the small dots, the values determined by meter measurements. The following table expresses numerically the values given in the rating curve:

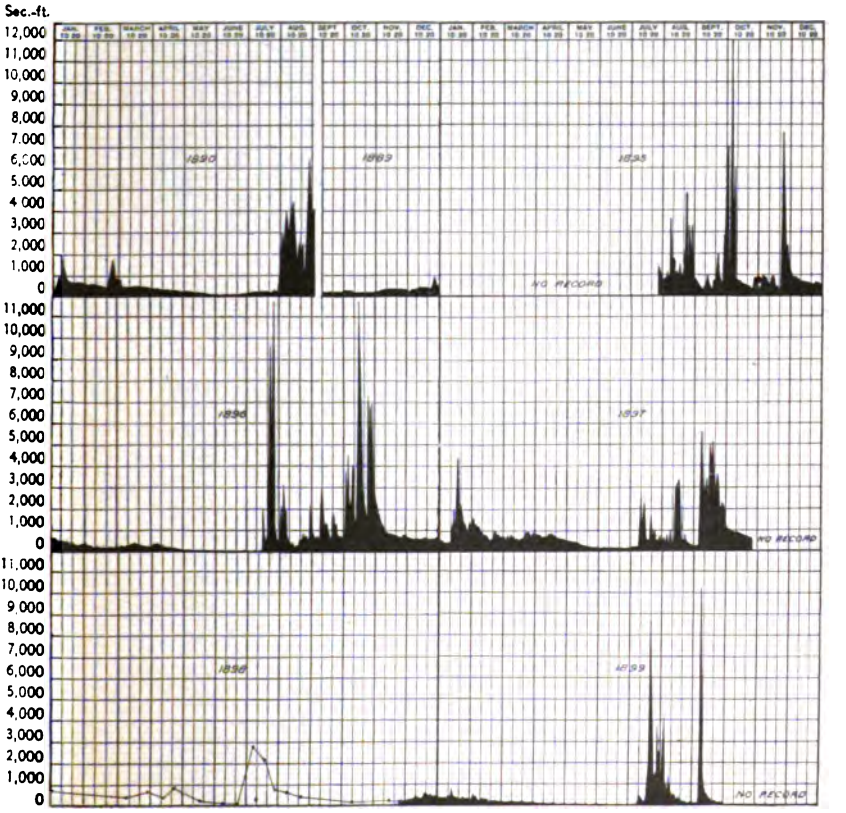
Rating table for Gila River at the Buttes, Arizona, from July 11, 1899, to August 10, 1899.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Sec.-ft.		*Sec.-ft.*		*Sec.-ft.*		*Sec.-ft.*
1.5	.....	2.7	250	3.9	1,445	5.1	3,364
1.6	0	2.8	320	4.0	1,550	5.2	3,548
1.7	1	2.9	410	4.1	1,670	5.3	3,732
1.8	5	3.0	500	4.2	1,800	5.4	3,916
1.9	9	3.1	605	4.3	1,950	5.5	4,100
2.0	15	3.2	710	4.4	2,100	6.0	5,020
2.1	25	3.3	815	4.5	2,260	6 5	5,940
2.2	40	3.4	920	4.6	2,440	7.0	6,960
2.3	60	3.5	1,025	4.7	2,625	7.5	7,780
2.4	90	3.6	1,130	4.8	2,810	8.0	8,700
2.5	130	3.7	1,235	4.9	2,995	8.5	9,620
2.6	180	3.8	1,340	5.0	3,180	9.0	10,540

From these daily measurements of area and frequent measurements of discharge, together with the rating tables mentioned above, the following table of volumes of discharge for Gila River at the Buttes from November 25, 1898, to September 30,1899, has been prepared.



A. RATING CURVE OF GILA RIVER AT THE BUTTES, ARIZONA. APPLIED FROM NOVEMBER 25, 1898, TO JULY 10, 1899.



B. DISCHARGE OF GILA RIVER AT THE BUTTES, ARIZONA, 1889–1899.

Estimated daily discharge of Gila River at the Buttes.

Day.	1898.				1899.							
	November.		December.		January.		February.		March.		April.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1	.....	.....	2.32	195	2.80	320	2.69	170	2.50	125	2.50	90
2	.....	.....	2.35	195	2.775	345	2.72	200	2.50	155	2.45	90
3	.....	.....	2.35	215	2.80	370	2.88	550	2.50	155	2.50	90
4	.....	.....	2.40	255	2.72	255	2.94	455	2.50	110	2.50	100
5	.....	.....	2.40	235	2.70	300	2.90	345	.....	110	2.50	100
6	.....	.....	2.40	255	2.65	275	2.77	410	2.50	110	2.50	100
7	.....	.....	2.45	255	2.60	255	2.69	235	2.50	155	2.45	80
8	.....	.....	2.45	255	2.62	275	2.71	235	2.50	155	2.45	70
9	.....	.....	2.50	275	2.67	255	2.72	200	2.50	110	.....	60
10	.....	.....	.....	275	2.60	235	2.70	300	2.50	140	2.45	60
11	.....	.....	2.60	275	2.72	275	2.77	255	2.40	140	2.45	50
12	.....	.....	2.72	410	2.95	480	2.80	300	.....	140	2.40	70
13	.....	.....	2.50	300	3.30	800	2.80	275	2.40	140	2.40	70
14	.....	.....	2.70	320	3.15	500	2.77	275	2.40	100	2.40	70
15	.....	.....	2.75	275	3.00	435	2.75	275	2.40	100	2.40	60
16	.....	.....	2.72	320	3.00	390	2.70	255	2.50	100	.....	60
17	.....	.....	2.80	320	2.95	345	2.67	170	2.55	110	2.40	60
18	.....	.....	2.85	300	2.92	345	2.67	170	2.55	155	2.40	60
19	.....	.....	2.90	480	2.80	320	2.66	140	.....	155	2.35	60
20	.....	.....	2.90	480	2.72	275	2.62	170	2.60	155	2.30	50
21	.....	.....	2.87	435	2.70	255	.....	170	2.60	155	2.30	60
22	.....	.....	2.90	410	2.70	235	2.65	170	.....	140	2.30	50
23	.....	.....	2.90	435	2.80	320	2.60	155	2.60	140	.....	50
24	.....	.....	2.95	390	2.80	370	2.60	200	2.50	140	2.30	60
25	2.10	105	.....	335	2.75	255	2.60	155	2.50	140	2.30	50
26	2.20	165	2.80	275	.....	300	2.60	155	.....	140	2.30	40
27	2.20	135	2.80	300	2.75	235	2.60	170	2.50	125	2.30	20
28	2.10	165	2.85	345	2.70	255	2.50	125	2.50	110	2.25	30
29	2.22	150	2.75	320	2.75	235	.....	.....	2.50	125	2.25	30
30	2.30	195	2.80	300	2.70	170	.....	.....	2.50	110	.....	30
31	.....	.....	2.80	320	2.70	185	.....	.....	2.50	100	.....	.....
Mean	.....	152	.....	305	.....	318	.....	239	.....	130.5	.....	62.3

Day.	May.		June.		July.		August.		September.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1	2.25	38	1.90	5	1.75	0.5	4.0	1,850	2.0	60
2	2.20	34	2.20	30	1.75	0.5	4.7	2,850	2.0	50
3	2.20	30	2.10	20	1.70	0.5	5.5	4,100	.....	45
4	2.20	30	.....	16	1.70	0.3	4.5	2,280	1.9	42
5	2.20	31	2.00	12	1.70	0.3	4.0	1,040	1.9	24
6	2.15	28	1.95	11	1.70	0.3	3.7	930	1.9	31
7	.....	26	1.90	16	1.70	0.2	3.3	660	3.28	1,300
8	2.15	25	1.90	6	1.70	0.2	4.5	1,380	8.3	10,187
9	2.15	24	1.90	5	.....	0.2	3.7	905	4.95	2,923
10	2.10	24	1.85	5	1.80	2	3.3	717	4.3	1,950
11	2.10	24	.....	4	2.75	300	3.3	460	3.5	1,382
12	2.10	23	1.80	4	2.80	320	3.1	515	3.0	734
13	2.10	23	1.80	2	2.70	250	2.8	397	2.8	510
14	.....	20	1.80	2	2.50	130	2.8	397	2.7	399
15	2.05	16	1.80	2	2.40	90	2.7	280	2.6	357
16	2.05	14	1.75	2	.....	170	2.6	215	2.5	288
17	2.00	12	1.75	1	2.70	250	2.5	315	2.4	249
18	2.00	13	.....	1	3.40	920	2.5	210	2.3	205
19	2.00	13	1.75	1	4.20	1,800	2.4	207	2.3	202
20	2.00	14	1.75	1	8.00	8,700	2.4	175	2.2	149
21	.....	12	1.75	1	5.50	4,100	.....	135	2.2	130
22	2.00	10	1.75	1	4.50	2,260	2.3	100	2.2	126
23	2.00	8	1.75	1	.....	1,900	2.3	120	2.1	99
24	2.00	9	1.75	1	4.00	1,550	2.2	90	2.1	108
25	2.00	11	.....	1	3.90	1,445	2.1	89	2.05	93
26	2.00	12	1.75	2	4.00	1,550	2.1	80	2.0	72
27	1.95	13	1.75	2	4.00	1,550	2.1	80	2.0	77
28	.....	10	1.75	1	5.25	3,640	2.0	70	2.0	68
29	1.95	9	1.75	1	4.50	2,440	2.0	71	2.0	68
30	1.90	6	.....	.....	4.20	2,475	2.0	60	.....	68
31	1.90	4	.....	.....	4.00	990	2.0	77	.....	.....
Mean	.....	18.2	.....	5.4	.....	1,188.0	.....	671.8	.....	733.1

Estimated monthly discharge of Gila River at the Buttes, Arizona.

[Drainage area, 17,834 square miles.]

Month.	Discharge in second-feet.			Total for month in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1889.						
September	210	90	128	7,616	0.010	0.009
October	210	140	157	9,655	0.013	0.011
November	250	156	212	12,614	0.017	0.015
December	890	124	275	16,909	0.023	0.020
1890.						
January	2,100	310	680	41,812	0.056	0.049
February	1,514	405	578	32,100	0.043	0.042
March	710	300	387	23,795	0.032	0.028
April	333	158	238	14,161	0.019	0.017
May	150	35	87	5,350	0.207	0.206
June	35	27	28	1,666	0.002	0.002
July	3,112	11	130	7,995	0.010	0.009
August	6,330	1,115	3,137	192,888	0.263	0.228
Total for season 1889-90			503	366,561	0.447	
1895.						
August	3,910	536	1,583	97,336	0.133	0.115
September	2,880	300	812	48,317	0.065	0.059
October	12,000	400	1,577	96,966	0.133	0.115
November	7,500	300	1,103	65,633	0.089	0.080
December	1,150	518	751	46,177	0.056	0.055
Total				354,429		
1896.						
January	500	250	396	24,349	0.032	0.028
February	340	175	209	12,027	0.016	0.015
March	356	153	242	14,880	0.021	0.018
April	340	68	180	10,711	0.014	0.013
May	68	12	32	1,968	0.002	0.002
June	32	1	5	298	0.000	0.000
July	11,708	1	1,441	88,604	0.121	0.105
August	3,150	175	810	49,805	0.068	0.059
September	2,850	455	980	58,314	0.079	0.071
October	11,793	1,030	4,145	254,868	0.347	0.301
November	2,275	696	1,037	61,706	0.083	0.075
December	710	576	629	38,676	0.053	0.046
Per annum	11,793	1	842	616,206	0.839	0.062
1897.						
January	4,310	400	1,286	79,074	0.108	0.094
February	1,580	560	883	49,039	0.066	0.064
March	920	520	702	43,165	0.059	0.051
April	800	520	694	41,296	0.056	0.050
May	440	94	224	13,773	0.018	0.016
June	83	20	52	3,094	0.004	0.004
July	2,360	00	565	34,741	0.047	0.041
August	3,270	160	799	49,129	0.067	0.058
September	5,590	106	2,371	141,084	0.192	0.172
October			800	49,190	0.067	0.058
				503,585		
1898.						
January			640	39,352		
February			485	26,936		
March			473	29,083		
April			547	32,549		
May			292	17,954		
June			252	14,995		
July			2,022	124,328		
August			537	33,018		
September			270	16,066		
October			79	4,858		
November			101	6,010		
December	480	195	305	18,753		
				393,902		

Estimated monthly discharge of Gila River at the Buttes, Arizona—Continued.

[Drainage area, 17,834 square miles.]

Month.	Discharge in second-feet.			Total for month in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1899.						
January	800	170	318	19,552	0.0209	0.0178
February	550	125	239	13,273	0.0135	0.0130
March	155	100	130.5	7,998	0.0080	0.0070
April	100	20	62.3	3,689	0.0040	0.0036
May	38	4	18.2	1,107	0.0010	0.0010
June	30	1	5.4	307	0.0003	0.0003
July	8,700	0.2	1,188.2	73,060	0.0767	0.0666
August	4,100	60	671.8	41,307	0.0437	0.0376
September	10,187	24	738.1	43,622	0.0460	0.0411
				208,910	0.2141	

From the foregoing data the following tables of annual discharge of Gila River at the Buttes and at San Carlos have been compiled:

Estimated annual discharge of Gila River at the Buttes and San Carlos, Arizona.

	Buttes.	San Carlos.[a]
	Acre-feet.	*Acre-feet.*
Seasonal year 1889–90, Sept. 1 to Aug. 31	366,561	329,905
Fractional year 1895, Aug. 1 to Dec. 31	354,429	318,986
Year 1896	616,206	554,585
Fractional year 1897, Jan. 1 to Oct. 3	503,585	453,227
Year 1898, approximate	363,902	327,512
Fractional year 1899, Jan. 1 to Sept. 30	203,910	183,519

[a] Ninety per cent of volume at the Buttes.

In order to get the greatest possible value from the records which have been compiled, and more particularly to make comparison with the annual rainfall records, the table given below has been prepared. In this statement every month in which measurements were taken is considered in the determination of an average monthly discharge for each month of the year. There are sixty months in all during which observations were made, there being five different years in which the flow was observed between January and September, inclusive, and four years in which November and December observations were made. From this table the mean monthly discharge is determined, and where a year has seven or more months of measured record, the remaining portion of it being deficient, the mean monthly discharge, as determined, is substituted for the months in which the record is defective. In this way a complete estimated record for five years is obtained, four months having been supplied for the year 1890, two for the year 1897, and three for the present year, 1899. A mean annual discharge is obtained by adding the mean monthly discharges actually measured, so that the mean annual discharge, which is 485,545 acre-feet, is determined only from actual measurements, and includes

all measurements that have been made. According to the census of 1890, there were but 6,619 acres irrigated from this great water supply, or less than 3 per cent of its possible utility. Practically the same area is irrigated at present as in 1890.

Estimated monthly mean, annual, and mean annual discharge, in acre-feet, of Gila River at the Buttes, Arizona.

[Drainage area, 17,834 square miles. Sixty months of observation.]

Year.	January.	February.	March.	April.	May.	June.
1890	41,812	32,100	23,795	14,161	5,350	1,666
1896	24,349	12,027	14,830	10,711	1,968	298
1897	79,074	49,039	43,165	41,296	13,773	3,094
1898	39,352	26,936	29,083	32,549	17,954	14,995
1899	19,552	13,273	7,993	3,689	1,107	307
Mean	40,828	26,675	23,783	20,481	8,030	4,072

Year.	July.	August.	September.	October.	November.	December.	Total.
1889			7,616	9,655	12,614	16,909	
1890	7,995	192,888	a52,506	a83,109	a36,491	a30,129	523,775
1895		97,336	48,317	96,966	65,633	46,177	
1896	88,604	49,805	58,314	254,868	61,706	38,676	616,206
1897	34,741	49,129	141,084	49,190	a36,491	a30,129	570,205
1898	124,828	33,018	16,066	4,858	6,010	18,753	363,902
1899	73,060	41,307	45,622	a83,109	a36,491	a30,129	353,639
Mean	65,745	77,247	52,506	83,109	36,491	30,129	469,093

a Approximate.

Using the data obtained from the above table to determine the probable conditions which would exist at San Carlos and at the Buttes, the table given below has been prepared. The amount of water measured at the Buttes is the basis of comparison, 90 per cent of the volume being taken as available at San Carlos during the years in which the observations were made. This table is given in order to determine the proper heights of dams to be constructed either at San Carlos or at the Buttes. From the volumes available annually have been deducted the contents of the reservoirs with the dams agreed upon for consideration in this report, and a column both for the Buttes and for San Carlos is given, showing the surplus water each year.

Volume, in acre-feet, available at the Buttes and at San Carlos, and surplus above capacity of respective reservoirs.

[Capacity of the Buttes reservoir, 174,040 acre-feet. Capacity of San Carlos reservoir, 241,396 acre-feet.]

Year.	The Buttes.		San Carlos.	
	Available.	Surplus.	Available.	Surplus.
1890	523,775	349,735	471,398	230,002
1896	616,206	442,166	554,585	313,190
1897	570,205	396,165	513,185	271,789
1898	363,902	189,862	327,512	86,116
1899	353,639	179,599	318,275	76,879
Mean	469,093	295,053	422,184	180,788

In order to make a comparison between the years in which observations of volumes discharged at the Buttes were made and years in which rainfall records were taken in the basin of Gila River, the diagram on Pl. III, *B*, is given. The rainfall data for this diagram is taken from the summary given on page 19, and is the mean for the entire basin of Gila River above the Buttes. The record begins in 1881 and extends to 1899, inclusive, covering eighteen years of rainfall record, that for 1899 being estimated for the period after September 1. Below the record of rainfall, which is in inches of depth, is given, for corresponding years, the volume discharged in acre-feet. It is desirable to determine whether years in which discharge measurements were made were years of excessive or deficient rainfall. It will be seen that the year 1897 is one of approximately average rainfall, and that in this year twice as much water was available for storage, either at San Carlos or at the Buttes, as the reservoirs could hold. The year 1898 was one of excessive rainfall, but it shows less run-off than the year 1897. This is probably accounted for by the nature of the storms occurring in the basin during that period, a greater portion of the water being absorbed by the ground and evaporated in 1898. The run-off from a hard rain is relatively higher than the run-off resulting from a slow rain or a gentle shower.

There is no record of discharge for the years of markedly deficient rainfall, unless it be the present year, 1899, for which the record is incomplete. During the first eight months of the year 1899 the rainfall for the portion of the basin above San Carlos was 6.40 inches, or 75 per cent of the mean. During this same period the precipitation for the San Pedro stations was 96 per cent of the mean. To August 1 the rainfall for the entire basin was 80 per cent of the usual precipitation. This would indicate for the present year a probable mean rainfall of 10.59 for the basin. The year for which we have the lowest record, as determined by our table, is 1885, when the average rainfall for the basin was 8.11 inches. This comparison is quite rough, but it gives some idea of the general conditions.

It will be seen from the above that the year 1899 is among the years of low run-off and rainfall. Numerous people were asked concerning the relative dryness of the year 1899 in Arizona. There was a unanimous verdict expressed to the effect that it was the driest year which they have had in the last ten, as regards both rainfall and the amount of water in the streams. From the table of volumes available at the Buttes and at San Carlos, the surplus which is estimated for the year 1899 is seen to be 179,599 acre-feet at the Buttes and 76,879 acre-feet at San Carlos. There is still a margin for drier years than the ones through which we have just passed.

It is, of course, impossible to predict absolutely that either of the reservoirs as projected would always be filled, but there is probability, if not certainty, that in all ordinary years, in all years of excessive rainfall, and in all years of ordinary drought the reservoirs will be

more than filled, and that only in conditions of excessive drought, surpassing those of record and of memory, is there a possibility that the reservoir as planned either at the Buttes or at San Carlos will not be completely filled. Even should it not be completely filled, it is certain that a partial supply will always be available, so that the irrigated lands supplied from this source can readily be brought through one season of drought without serious damage. These periods of excessive drought are not likely to occur oftener than once every fifteen years.

From the data and tables given in the previous paragraphs, it is considered that, as far as the water supply is concerned, a dam 170 feet high at the Buttes, storing 174,040 acre-feet of water, or a dam 130 feet high at San Carlos, storing 241,396 acre-feet of water, can be built with every assurance of success. The statement is ventured that there are no reservoirs in arid America that have a more certain water supply, proportional to their capacity, than these proposed reservoirs on the Gila River.

EVAPORATION.

In the Twelfth Annual Report of the Survey, page 308, there is given a table showing the probable monthly evaporation from a water surface in Arizona, from observations made in the Southwest by the Survey. This is accepted as the basis of estimates for evaporation in this report:

Loss by evaporation from a water surface.

Month.	Quantity.	Month.	Quantity.
	Inches.		*Inches.*
January	3	August	13
February	4	September	10
March	6	October	6
April	7	November	5
May	10	December	4
June	11		
July	12	Total	91

It is obvious that in order to obtain an approximate idea of the loss by evaporation from a reservoir, an estimate must be made of the area that will be exposed to evaporation. For this purpose the following table has been prepared. It is assumed that 100,000 acre-feet of water should be in the Buttes reservoir at the end of the irrigation season, or on November 1, of each year. The amount of water, in acre-feet, that will probably flow into the reservoir during November has been obtained from the table of the estimate of monthly mean, annual, and mean annual discharges of the river at the Buttes. The amount of inflow for each month is added to the amount of water available from the previous months. The annual consumption from the reservoir is assumed to be the capacity of a completely filled reservoir, which in the case of the Buttes is 174,040 acre-feet. The amount of this water consumed each month has been estimated in the column marked "Portion of reservoir used."

It is assumed that a certain amount of water will always be required in the canals, even in winter time, for the irrigation of annual plants and to provide for domestic and stock water. The fifth column of the table is entitled "Outflow for irrigation," and is given for each month of the year. This is obtained by multiplying the annual consumption by the per cent used each month. This monthly consumption is deducted from the amount available in the reservoir at the end of each month, and from these figures the mean area of the water surface in the reservoir each month is obtained and given in column six, entitled "Area exposed to evaporation." The depth of evaporation for each month is then taken from the above, and the resulting loss by evaporation is shown in the eighth column, entitled "Loss by evaporation." The next column shows the total loss from the reservoir from evaporation and irrigation; the tenth column, the remainder in the reservoir at the end of each month, and the eleventh column, the amount that is wasted from a full reservoir, the capacity of the reservoir being 174,040 acre-feet, and the annual outflow of the basin at the Buttes being estimated as 469,093 acre-feet, as shown in the table on page 30. In an average year the total waste is 198,590 acre-feet of water.

The loss by evaporation under the above conditions would be 22,370 acre-feet, but there still would be available from the reservoir for irrigation its full capacity of 174,040 acre-feet of water. It is of interest to note that under the above conditions there never would be less than 132,320 acre-feet of water in the reservoir, which is sufficient to provide for a complete summer irrigation, in case the stream should be entirely dry for a period of five months.

Hypothetical summary of amount of water in the Buttes reservoir each month, with use, evaporation, and surplus.

Month.	Contents of reservoir at beginning of month.	Inflow.	Portion of reservoir used.	Outflow for irrigation.	Area exposed to evaporation.	Depth of evaporation.	Loss by evaporation.	Total loss from evaporation and irrigation.	Balance in reservoir at end of month.	Amount wasted over dam.
	Acre-ft.	*Acre-ft.*	*P. ct.*	*Acre-ft.*	*Acres.*	*Feet.*	*Acre ft*	*Acre ft*	*Acre-ft.*	*Acre-ft.*
November	109,000	36,500	2	3,480	2,350	0.42	990	4,470	132,030	.....
December	132,030	30,100	2	3,480	2,800	.333	700	4,180	157,950	.....
January	157,950	40,800	2	3,480	3,070	.25	770	4,250	174,040	20,460
February	174,040	26,700	5	8,700	3,150	.333	1,050	9,750	174,040	16,950
March	174,040	23,800	7	12,180	3,150	.50	1,580	13,760	174,040	10,040
April	174,040	20,500	9	15,660	3,150	.58	1,830	17,490	174,040	3,010
May	174,040	8,600	14	24,370	3,000	.833	2,500	26,870	155,200	.....
June	155,200	4,070	14	24,370	2,800	.92	2,580	26,950	132,320	.....
July	132,320	65,740	13	22,630	2,770	1.00	2,770	25,400	172,660	.....
August	172,660	77,200	13	22,630	3,150	1.08	3,400	26,030	174,040	49,790
September	174,040	52,500	11	19,140	3,150	.833	2,620	21,760	174,040	30,740
October	174,040	83,100	8	13,920	3,150	.50	1,580	15,500	174,040	67,600
Total	.....	469,040	100	174,040	.....	7.58	22,370	196,410	.....	.....

As the conditions above named are all assumed, the figures used are round numbers. It is probable that a more complete knowledge of the stream will permit of a greater annual consumption by irrigation than the capacity of the reservoir alone would indicate. The driest year of which we have any record would permit the use of 174,040 acre-feet of water from the Buttes reservoir, with a substantial reserve.

Accurate observations of evaporation are always difficult to obtain, owing to variation in wind velocities and general exposure of the evaporating pan. The effort should be made to have conditions in the evaporation pan that would be similar to those existing in the reservoir, from which the loss from this source is to be determined. For this reason it is necessary to float the evaporation pan in the river or in a canal, and the fluctuations of the water surface are often so great that the pan is frequently either upset or entirely lost. Rain falling on the pan has also to be considered, and it is known that the amount of catchment in a pan 3 feet square is relatively larger than the catchment in a standard rain gage, the diameter of whose cup is 8 inches. In the Twelfth Annual Report of the Survey, page 235, is given a statement of some evaporation observations made in the Southwest. These do not cover complete months and may be misleading.

Observations of evaporation from graduated tubes were made at the Buttes from January to July, 1899. These tubes were exposed in the shade, and the wind was prevented from acting directly on the water's surface. The results obtained are of doubtful value and are not used. In July, 1899, an evaporating pan was floated in the river at the Buttes, but the record was so much interfered with by high water upsetting the pan that it is considered unreliable. Later the attempt was made to float the pan in an artificial pond.

SPILLWAY PROVISIONS.

The accompanying illustrations, Pls. V, IX, and XII, exhibit the conditions at the Buttes dam site, and show the principal features of the proposed spillway. In the report by Mr. Davis, of 1896, he determined the maximum flood that would have to be provided for at the dams in this stream, as follows:

> The first consideration in plans for a dam under the circumstances here presented is the provision for a safe and adequate spillway. The large catchment area of this stream, its mountainous character, the paucity of soil and vegetation on these mountains, exposing considerable area of bare rock on steep slopes, and the sudden and violent nature of the summer rainstorms indicate the necessity of a spillway of large proportions. What this capacity should be is recognized as one of the important and difficult problems. The best evidence thus far obtained regarding past freshets on this river was kindly furnished by Mr. Albert T. Col-

ton. The greatest rise so far recorded on the Gila River occurred on the 22d of February, 1891. Considerable evidence was obtained that no such flood has occurred since a date many years before the advent of the white man. Irrigating ditches supposed to be extremely old were overflowed and destroyed. Lands were overflowed that had retained no evidence of any previous inundation.

On June 12, 1892, about sixteen months after this flood, Mr. Colton found marks of high water on both banks of the river far above any of the ordinary freshets, which he attributed to the great flood. This point was about 3¼ miles below the head of the Florence canal, or approximately 6 miles below the Buttes. With his level he took a cross section of the river at this point and measured the slope of the channel. The cross section he obtained was 6,600 square feet. The slope measured was 10.56 feet per mile. The channel was sandy and free of brush or large bowlders or other obstructions for a distance of 300 feet above and 300 feet below the cross section. This information, meager as it is, is the best we have upon which to estimate the discharge of the river at that time.

The difficulty in obtaining correct results of this discharge lies in the uncertainty of the retarding effect of the channel upon the flow of the water. This retarding effect in a rough river bed is very great. Assuming this quantity as small as it could possibly be, a computation of the discharge was made, using Kutter's formula. The factor of roughness designated in the formula as "n" was taken as 0.025. Not that this was considered the correct factor, as it is almost certainly too small, but by assuming the smallest possible value of "n" we obtain the largest discharge, and it is the largest discharge that should be provided for in the construction of a spillway. It is thought, therefore, that this computation will give conservative results, and that a spillway based upon the discharge obtained would be safe. The result obtained was 102,566 cubic feet per second. And it is to accommodate this discharge that the spillway is planned. It will be seen at once that no such spillway could be economically provided artificially, and that the accommodation of the topography to the provision of this spillway is one important determining feature of the location and height of the dam.

SILT.

The following further quotation is made from the same report of Mr. Davis:

The amount of solid material carried by such a stream as the Gila can be learned only by impounding it. As it is considerable, it is obvious that a reservoir built on this water course will eventually fill with solid matter unless means are provided for its removal. No entirely sufficient plan for this purpose has ever been put in operation. It is usually assumed, and often with truth, that the life of the reservoir is sufficiently long to justify its construction even though it will eventually fill and have its usefulness destroyed. This disposition of the problem, however, is not applicable to the present case. The amount of material carried by this stream is too large and the necessity of the reservoir to the life of the district to be irrigated from it is too vital to justify this convenient solution or, rather, evasion of the problem.

The most astonishing accounts are obtained from the inhabitants of this region of the quantity of silt carried in suspension by this stream when in flood. Many people in their emphatic expressions place the quantity at one-half the volume, though, of course, this is impossible. It is said, however, that in the months of July and August, when the surface of the ground is exceedingly dry, when it has been ground to powder even in the most isolated and apparently inaccessible

localities by range cattle and horses in search of grass, when the great torrential "cloud-bursts," to which this country is subject, fall upon such ground and rush off the steep slopes into the stream with prodigious velocity, the amount of silt carried in suspension by the roaring torrent is very great.

* * * * * * *

Attempts have been made, however, by private parties from time to time to measure the amount of suspended material. The most important and reliable of these measurements were those made by Mr. Albert T. Colton in the month ending August 7, 1893, and by Mr. W. Richins at the Buttes. Mr. Colton found the percentage of silt by volume averaged 2.2 per cent. As these observations were taken and reduced by Mr. Colton, who is a competent engineer, they are adopted as correct. The observations by Mr. Richins extended from July 29 to December 31, 1895. They were taken by the following method:

A sample of the water was poured into a slender glass tube until it reached the height of 100 divisions on a convenient scale, and was then allowed to settle several days, until the main portion of the water was clear. The height of the sediment on the same scale was then read and the result recorded as the percentage of mud carried by the water. The existence of this record, and the ease with which more of such observations could be taken, made it important that an approximate relation be established between the volume of this mud and that of the actual solid matter it contained. For this purpose several laboratory determinations have been made with muddy samples of Gila water by settling and reading the volume of mud as above and then drying the residue at 100° C. and determining its volume.

These observations indicate an average ratio of dry matter to mud of about one-fifth, and this factor has been used to reduce the mud observations of Mr. Richins to solid matter.

* * * * * * *

It should be remembered that these observations take no account of material that is rolled on the bottom of the stream.

On page 32 of Mr. Davis's report of 1896 a table is given showing the percentage of mud and solid matter carried each day from July 29 to December 31 in Gila River at the Buttes. The following table gives, in columns Nos. 3 and 4, this percentage of mud and of solids. In column No. 2 the number of acre-feet discharged on corresponding dates is given, and columns Nos. 5 and 6 give the number of acre-feet of mud and solids for the same dates. During this period the volume of water discharged at the Buttes was 360,523 acre-feet, and from the table it is found that 37,984 acre-feet of mud was carried in suspension by this water. This, reduced by the ratio of 5 to 1, as adopted by Mr. Davis, gives 7,704 acre-feet of solids. The average amount of mud during this period is 10.5 per cent.

Discharge of sediment of Gila River at the Buttes for 1895.

[Observer, W. Richins.]

Day.	July.					August.				
	Water.	Mud.	Solids.	Mud.	Solids.	Water.	Mud.	Solids.	Mud.	Solids.
	Acre-ft	*Per ct.*	*Per ct.*	*Acre-ft*	*Acre-ft*	*Acre-ft*	*Per ct.*	*Per ct.*	*Acre-ft*	*Acre-ft*
1	.....	.....	.....	.....	.....	1,101	15	3.0	159	32
2	.....	.....	.....	.....	.....	1,631	20	4.0	326	65
3	.....	.....	.....	.....	.....	1,505	20	4.0	301	60
4	.....	.....	.....	.....	.....	2,479	20	4.0	496	99
5	.....	.....	.....	.....	.....	1,733	20	4.0	347	69
6	.....	.....	.....	.....	.....	1,806	20	4.0	361	72
7	.....	.....	.....	.....	.....	1,956	15	3.0	293	59
8	.....	.....	.....	.....	.....	6,861	20	4.0	1,372	274
9	.....	.....	.....	.....	.....	3,247	15	3.0	487	97
10	.....	.....	.....	.....	.....	3,406	15	3.0	511	102
11	.....	.....	.....	.....	.....	3,326	15	3.0	499	100
12	.....	.....	.....	.....	.....	2,554	12	2.4	307	61
13	.....	.....	.....	.....	.....	2,273	7	1.4	159	32
14	.....	.....	.....	.....	.....	2,475	7	1.4	173	35
15	.....	.....	.....	.....	.....	2,178	7	1.4	152	30
16	.....	.....	.....	.....	.....	3,168	7	1.4	222	44
17	.....	.....	.....	.....	.....	2,178	7	1.4	152	30
18	.....	.....	.....	.....	.....	2,000	7	1.4	142	28
19	.....	.....	.....	.....	.....	1,881	7	1.4	132	26
20	.....	.....	.....	.....	.....	2,109	7	1.4	148	30
21	.....	.....	.....	.....	.....	2,709	7	1.4	190	38
22	.....	.....	.....	.....	.....	7,742	7	1.4	542	108
23	.....	.....	.....	.....	.....	7,346	7	1.4	514	103
24	.....	.....	.....	.....	.....	2,485	7	1.4	174	35
25	.....	.....	.....	.....	.....	2,257	7	1.4	158	32
26	.....	.....	.....	.....	.....	6,376	7	1.4	446	89
27	.....	.....	.....	.....	.....	3,802	7	1.4	266	53
28	.....	.....	.....	.....	.....	3,326	7	1.4	233	47
29	2,851	20	4	570	114	6,376	17	3.4	1,084	217
30	2,039	20	4	408	82	2,851	15	3.0	428	86
31	1,204	17	3.4	205	41	2,020	15	3.0	302	60
Total	6,094	.....	.....	1,183	237	97,336	.....	.....	11,076	2,213

Day.	September.					October.				
	Water.	Mud.	Solids.	Mud.	Solids.	Water.	Mud.	Solids.	Mud.	Solids.
	Acre-ft	*Per ct.*	*Per ct.*	*Acre-ft*	*Acre-ft*	*Acre-ft*	*Per ct.*	*Per ct.*	*Acre-ft*	*Acre-ft*
1	1,663	17	3.4	286	57	13,860	20	4.0	2,772	554
2	1,693	17	3.4	286	57	1,683	15	3.0	252	50
3	1,465	15	3.0	220	44	1,980	15	3.0	297	59
4	1,386	15	3.0	208	42	23,760	20	4.0	4,752	950
5	1,267	12	2.4	152	30	5,940	20	4.0	1,188	238
6	1,109	10	2.0	111	22	11,880	20	4.0	2,376	475
7	990	5	1.0	50	10	7,920	20	4.0	1,584	317
8	891	4	.8	36	7	3,960	15	3.0	597	119
9	792	1	.2	8	2	1,980	12	2.4	238	48
10	990	5	1.0	50	10	1,624	10	2.0	162	32
11	1,980	15	3.0	297	59	1,465	10	2 0	147	29
12	1,624	15	3.0	244	49	1,386	5	1.0	69	14
13	1,267	12	2.4	152	30	1,267	3	.6	38	8
14	1,267	12	2.4	152	30	1,267	3	.6	38	8
15	792	12	2.4	95	19	1,109	2	.4	22	4
16	594	12	2.4	71	14	1,109	2	.4	22	4
17	634	8	1.6	51	10	1,109	2	.4	22	4
18	634	15	3.0	95	19	1,109	2	.4	22	4
19	1,386	20	4.0	277	55	1,109	2	.4	22	4
20	1,624	20	4.0	325	65	990	2	.4	20	4
21	3,960	20	4.0	792	158	990	2	.4	20	4
22	2,099	20	4.0	420	84	990	2	.4	20	4
23	1,782	20	4.0	356	71	792	2	.4	16	3
24	1,782	20	4.0	356	71	792	2	.4	16	3
25	1,327	17	3.4	226	45	792	2	.4	16	3
26	1,228	17	3.4	209	42	792	2	.4	16	3
27	634	17	3.4	108	22	792	2	.4	16	3
28	1,327	20	4.0	265	53	792	2	.4	16	3
29	4,356	20	4.0	871	174	1,782	15	3.0	267	53
30	5,702	20	4.0	1,140	228	990	10	2.0	99	20
31	.....	.....	.....	.....	.....	792	5	1.0	40	8
Total	48,317	.....	.....	7,809	1,579	96,966	.....	.....	15,182	3,032

Discharge of sediment of Gila River at the Buttes for 1895—Continued.

Day.	November.					December.				
	Water.	Mud.	Solids.	Mud.	Solids.	Water.	Mud.	Solids.	Mud.	Solids.
	Acre-ft	*Per ct.*	*Per ct.*	*Acre-ft*	*Acre-ft*	*Acre-ft.*	*Per ct.*	*Per ct.*	*Acre-ft*	*Acre-ft*
1	792	5	1.0	40	8	2,277	2	0.4	46	9
2	792	3	.6	24	5	2,020	2	.4	40	8
3	792	3	.6	24	5	1,822	2	.4	36	7
4	1,980	5	1.0	99	20	1,822	2	.4	36	7
5	1,822	5	1.0	91	18	1,822	2	.4	36	7
6	1,822	3	.6	55	11	1,822	2	.4	36	7
7	1,228	3	.6	37	7	1,663	1	.2	17	3
8	1,228	3	.6	37	7	1,663	1	.2	17	3
9	1,228	2	.4	25	5	1,663	1	.2	17	3
10	1,109	2	.4	22	4	1,525	1	.2	15	3
11	1,109	2	.4	22	4	1,527	1	.2	15	3
12	1,822	3	.6	55	11	1,471	1	.2	15	3
13	1,980	3	.6	59	12	1,471	0	.0	0	0
14	1,822	2	.4	36	7	1,471	0	.0	0	0
15	1,228	2	.4	25	5	1,416	0	.0	0	0
16	990	0	.0	0	0	1,416	0	.0	0	0
17	792	0	.0	0	0	1,416	0	.0	0	0
18	792	0	.0	0	0	1,360	1	.2	14	3
19	634	0	.0	0	0	1,360	1	.2	14	3
20	634	0	.0	0	0	1,360	1	.2	14	3
21	634	0	.0	0	0	1,305	0	.0	0	0
22	594	3	.6	18	4	1,249	0	.0	0	0
23	2,277	5	1.0	114	23	1,360	0	.0	0	0
24	14,850	5	1.0	743	149	1,471	2	.4	29	6
25	4,752	5	1.0	238	148	1,360	2	.4	27	4
26	4,752	3	.6	143	28	1,305	1	.2	13	3
27	4,158	3	.6	125	25	1,249	1	.2	12	2
28	3,366	3	.6	101	20	1,192	1	.2	12	2
29	2,970	3	.6	89	18	1,137	0	.0	0	0
30	2,574	2	.4	51	10	1,081	0	.0	0	0
31						1,026	0	.0	0	0
Total	65,633			2,273	554	46,177			461	89

Beginning on January 1, 1899, and continuing until July 31, 1899, silt observations were again maintained at the Buttes, the amount of mud and silt being determined as was done in 1895. The results are shown in the following table. This differs slightly in construction from the previous table, but gives results which correspond with it. Column No. 2 gives the daily discharge of the river in second-feet, column No. 3 the per cent of solids, and column No. 4 the solids in second-feet. From the mean monthly discharge in second-feet of water and of solids, the acre-feet of each for each month is determined, as indicated. The total amount of water discharged during the first seven months of 1899 was 118,981 acre-feet, and the amount of solids determined was 1,893 acre-feet, or 1.6 per cent of solids or 8 per cent of mud.

Adding the total number of acre-feet of water during the period of silt observations in 1895 to the acre-feet of water discharged in 1899 gives 479,504 acre-feet of water and a total amount of solids during the entire period of 9,597 acre-feet. From these figures an average of 2 per cent of solids for the entire period of observation is determined. It will be noted that the observations in 1895 began on July 29 and extended to December 31, while the observations of 1899 began January 1 and extended to July 31, inclusive, making one complete year and three days. The total mean annual discharge of water of Gila

Discharge of sediment of Gila River at the Buttes for 1899.

[Observer, C. W. Lemon.]

Day.	January.			February.			March.		
	Water.	Solids.	Solids.	Water.	Solids.	Solids.	Water.	Solids.	Solids.
	Sec.-ft.	*Per ct.*	*Sec.-ft.*	*Sec.-ft.*	*Per ct.*	*Sec.-ft.*	*Sec.-ft.*	*Per ct.*	*Sec.-ft.*
1	320	1.0	0.64	170	0.1	0.03	125	0.1	0.02
2	345	1.0	.69	200	.1	.04	155	.1	.08
3	370	1.0	.74	550	.3	.33	155	.1	.08
4	255	1.0	.51	455	.3	.29	110	.1	.02
5	300	1.0	.60	345	.2	.16	110	.1	.02
6	275	1.0	.55	410	.2	.16	110	.1	.02
7	255	1.0	.51	235	.1	.05	155	.1	.08
8	275	1.0	.55	235	.2	.09	155	.1	.08
9	255	1.0	.51	200	.1	.04	110	.1	.02
10	235	1.0	.47	300	.1	.06	140	.1	.08
11	275	1.0	.55	255	.1	.05	140	.1	.08
12	480	1.0	.96	300	.1	.06	140	.1	.08
13	800	1.0	1.60	275	.1	.05	140	.1	.08
14	500	1.0	1.00	275	.5	.27	100	.1	.02
15	435	1.0	.87	275	.8	.44	100	.1	.02
16	390	1.0	.78	255	.4	.20	100	.1	.02
17	345	1.0	.69	170	.4	.14	110	.1	.02
18	345	1.0	.69	170	.4	.14	155	.1	.08
19	320	1.0	.64	140	.4	.11	155	.1	.08
20	275	.3	.16	170	.3	.10	155	.1	.08
21	255	.2	.10	170	.3	.10	155	.1	.08
22	235	.2	.09	170	.3	.10	140	.1	.08
23	320	.3	.19	155	.3	.09	140	.1	.08
24	370	.2	.15	200	.3	.12	140	.1	.08
25	255	.2	.10	155	.2	.06	140	.1	.08
26	300	.2	.12	155	.2	.06	140	.1	.08
27	235	.3	.14	170	.2	.07	125	.1	.02
28	255	.3	.15	125	.2	.05	110	.1	.02
29	235	.3	.14				125	.1	.02
30	170	.1	.03				110	.1	.02
31	185	.1	.04				100	.1	.02
Mean, sec.-feet	318		.48	239		.12	130.5		.12
Acre-feet	19,552		30	13,273		7	7,998		1.0

Day.	April.			May.			June.			July.		
	Water.	Solids.	Solids.	Water.	Solids.	Solids.	Water.	Solids.	Solids.	Water.	Solids.	Solids.
	Sec.-ft.	*P. ct.*	*S.-ft.*	*Sec.-ft.*	*P. ct.*	*Sec.-ft.*	*Sec.-ft.*	*P. ct.*	*Sec.-ft.*	*Sec.-ft.*	*P. ct.*	*Sec.-ft.*
1	90	T.	0.01	38	T.	0	5	T.	0	5	T.	0
2	90	T.	.01	34	T.	0	36	T.	0	5	T.	0
3	90	T.	.01	30	T.	0	26	T.	0	5	T.	0
4	100	T.	.01	30	T.	0	16	T.	0	3	T.	0
5	100	T.	.01	31	T.	0	12	T.	0	3	T.	0
6	100	T.	.01	28	T.	0	11	T.	0	3	T.	0
7	80	T.	.01	26	T.	0	16	T.	0	2	T.	0
8	70	T.	.01	25	T.	0	6	T.	0	2	T.	0
9	60	T.	.01	24	T.	0	5	T.	0	2	T.	0
10	60	T.	.01	24	T.	0	5	T.	0	2	T.	0
11	50	T.	.01	24	T.	0	4	T.	0	300	27	16.20
12	70	T.	.01	23	T.	0	4	T.	0	320	26	16.64
13	70	T.	.01	23	T.	0	2	T.	0	250	20	10.00
14	70	T.	.01	20	T.	0	2	T.	0	130	20	5.20
15	60	T.	.01	16	T.	0	2	T.	0	90	18	3.24
16	60	T.	.01	14	T.	0	2	T.	0	170	12	4.08
17	60	T.	.01	12	T.	0	1	T.	0	250	24	12.00
18	60	T.	.01	13	T.	0	1	T.	0	920	10	18.40
19	60	T.	.01	13	T.	0	1	T.	0	1,800	22	79.20
20	50	T.	.01	14	T.	0	1	T.	0	8,700	14	243.60
21	60	T.	.01	12	T.	0	1	T.	0	4,100	10	82.00
22	50	T.	.01	10	T.	0	1	T.	0	2,260	14	63.28
23	50	T.	.01	8	T.	0	1	T.	0	1,900	15	57.00
24	60	T.	.01	9	T.	0	1	T.	0	1,550	10	31.00
25	50	T.	.01	11	T.	0	1	T.	0	1,445	10	28.90
26	40	T.	.01	12	T.	0	2	T.	0	1,550	8	24.80
27	20	T.	.01	13	T.	0	2	T.	0	1,550	7	21.70
28	30	T.	.01	10	T.	0	1	T.	0	3,640	10	72.80
29	30	T.	.01	9	T.	0	1	T.	0	2,440	15	73.20
30	30	T.	.01	6	T.	0				2,475	10	49.50
31				4	T.	0				990	12	23.76
Mean, sec.-ft.	62.3		.01	18.2		0	5.4		0	1,188.2	30.21	
Acre-feet	3,689		1.0	1,107		0	30.7		0	73,060	1,854	

T.—Trace.

River at the Buttes has been determined as 469,093 acre-feet. If 2 per cent of this volume be considered as solids, it will indicate an annual discharge of solids of 9,382 acre-feet, which corresponds very closely with the 9,597 acre-feet determined in the twelve months during which observations occurred.

The capacity of the Buttes reservoir, with the dam 150 feet high to the spillway, is 174,040 acre-feet. If 9,711 acre-feet of solid matter is delivered to the reservoir each month, and it all settles in passing through the basin, this reservoir would fill with solid matter in eighteen and six-tenths years. The mean annual flow of water of Gila River at San Carlos has been determined as 422,184 acre-feet. If 2 per cent of this volume is solids, there would be delivered to the reservoir 8,443 acre-feet of solids per annum. The capacity of the San Carlos reservoir, with the dam as planned, 130 feet high to the spillway, is 241,396 acre-feet. If 8,443 acre-feet of solid matter should be delivered to this reservoir each year and should be deposited therein, it would fill in twenty-eight and five-tenths years.

These figures show the exceeding gravity of the silt proposition on Gila River. No other stream is known in America which carries such large volumes of débris. It is evident that some provision must be made to avoid the destruction of the reservoir or the building of the dam would be useless. It would be cruel to develop a civilization upon irrigation which would have to be destroyed at the end of a generation. It is extremely fortunate that there is more than one reservoir site on Gila River the water from which would be available for irrigation in the neighborhood of the Gila River Indian Reservation. If a dam should be constructed at San Carlos and the reservoir become filled with silt, it would be possible to construct at the end of the twenty-eight and five-tenths years a second dam at Riverside of equal capacity, and after that reservoir became filled with silt the dam at the Buttes could be built. A fourth reservoir site of considerable value may be found at Guthrie, above the Solomonville Valley, on the same stream, and of large capacity. In the case of all these dams the capacity increases very rapidly with an increased height of dam. For instance, if the Buttes dam should be raised 10 feet above the 150-foot contour, its capacity would be increased 33,755 acre-feet; and if raised 20 feet, its capacity would be increased 72,355 acre-feet. If the San Carlos dam should be increased in height 20 feet, its storage capacity would be increased 135,780 acre-feet. It would therefore be possible to very greatly increase the storage capacity of these reservoirs by building the dams to greater heights as the basin filled with mud. The spillways of the San Carlos dam, as planned, could be raised 1.24 feet in height, increasing the capacity of the reservoir to that extent at small cost, without endangering the structure.

The silt which is carried by Gila River is exceedingly light and requires a number of days to settle in a test tube, and it is believed that

a portion of it will remain in suspension until it is carried over the spillway or through the gates. As irrigation is practiced on the flat lands of the Gila Valley the water plane in that district will be raised much nearer to the surface than it is now, and less irrigation will be necessary. Numerous points are known in the San Joaquin Valley, in California, where water could not be obtained in wells prior to irrigation, and where now, after twenty years of irrigation, water is standing at the surface. Near Fresno, California, the water plane has risen to such an extent that but one irrigation a year is needed on the vineyards.

When the irrigation country has developed to the extent that all water available from the reservoir is required, and when the reservoir has reached the point where the silting endangers the community, it probably will be advisable to construct a large storm channel around the margin of the reservoir and above the maximum water line to carry as much as possible of the water of the river. Such portion of the water as is needed for irrigation below can be passed through this canal without stopping in the reservoir and may be diverted at the proper point near the irrigated fields. This canal could be constructed of large section for the first portion of its course and the section afterwards reduced. A spillway should be located at the point where the canal is reduced in capacity and the excessive water be drawn from the top of the canal into the reservoir. A larger portion of the sediment which would travel in the bottom of the channel would remain in the conduit, and the clarified water would be discharged into the reservoir. A velocity may be maintained in the remaining portion of the canal sufficient to carry the silt through it to the river below the dam.

The suggested canal, being above the maximum water line, would provide an effective head for hydraulic giants for sluicing the silt which had previously been deposited in the reservoir. On favorable occasions, when the reservoir was practically empty, this sluicing or washing out of the basin could be practiced. On July 11, 1899, there was 27 per cent of mud in Gila River at the Buttes. This is the greatest amount of sediment ever observed in this river. From this it will be seen that the suspended matter is exceedingly light, and it would therefore be possible to move large quantities of this loose mud with hydraulic giants and carry it in temporary flumes, or even in the river channel itself, through openings in the dam. Experience with light silt in constructed reservoirs elsewhere shows the greatest deposits to occur where the water is deepest, which is near the dam. Here is also the greatest storage capacity of the basin.

The drop from the storm canal to the bed of the river below the dam would probably be not less than 150 feet. If 500 cubic feet of water per second should be discharged through this canal, over 8,475 theoretical horsepower could be developed. During certain periods

of the year Gila River is almost dry, and this power would not be available from the canal; but when such occasions existed in the river the reservoir would necessarily be drawn upon for irrigation, and power could be obtained from the discharge from the reservoir. It is possible that from 2,000 to 5,000 horsepower could be developed in this manner. The section of Arizona in the neighborhood of San Carlos is highly mineralized. Copper mines of great value are to be found at Globe and at Riverside. New and effective processes have been discovered for reducing copper matte electrically. Fuel is high priced. On the above basis it is reasonable to presume that when the time arrives for the building of the storm canal around the reservoir sufficient revenue can be obtained from power to pay the interest on the cost of construction of the storm ditch. This power could also be used in cleaning out the reservoir with hydraulic dredges.

While the deposit of silt in the reservoir is probably the most serious question in connection with the impounding of water on the Gila, it is believed, on the basis of the above arguments, that the situation could be controlled and that the reservoir may be made to do service through a long period of years, if not indefinitely.

EXPLORATIONS FOR BED ROCK AT THE BUTTES.

The material that covers the bed rock at the Buttes and at Queen Creek is a sand and gravel saturated with water in the bed of a canyon, through which varying volumes of water might be expected to be discharged, ranging from 100 cubic feet per second to 1,000 cubic feet per second during the periods of low water on the river. These low stages of the river might be expected to exist from the 1st of April to the 1st of July, after which violent floods of much greater volume would probably occur at the Buttes dam site.

On Queen Creek large bowlders occur at the surface, and although the stream might be expected to be entirely dry during corresponding dates, after that time violent floods might occur any day. Great reticence was felt on the part of everyone in giving figures that should be regarded as even roughly approximate for this work. Numerous well drillers were interviewed in San Francisco and in southern California, and none cared to bid, under the conditions. Two methods of going to bed rock were suggested—one by means of open shafts, and the other by the use of the diamond core drill. Only one bid was received in reply to proposals, and that at the rate of $15 per linear foot. This was rejected as too high. It was admitted by all that the diamond core drill would work accurately and easily in solid rock, but when it came to going through bowlders of varying size it was conceded to be exceedingly difficult, if not wholly impracticable.

As stated above, the one bid was rejected, and the Geological Survey carried on this work at the points in question, and succeeded in thoroughly solving the problem, largely owing to the experience which Mr. Arthur P. Davis had acquired in work in Nicaragua.

A. DIAMOND-CORE DRILL PARTY AT WORK.

B. BUTTES RESERVOIR SITE.

DIAMOND CORE DRILL.

As this work was somewhat unique, it will be of interest to give its progress in detail, together with a description of the tools employed. In considering the matter of going down with a shaft the most serious problems would be the water encountered. In working with a shaft the river would have to be carried in a flume by the works for a long distance. A large pump would have to be kept going constantly in the shaft, and it is doubtful if under the most favorable conditions it would be able to handle the amount of water which would be encountered. Pumps with valves would be barred on account of the large amount of sand suspended in the water. It was estimated that it would cost $46 per vertical foot to sink shafts under these conditions. This would permit of putting down about four holes at the Buttes with the funds available, with bed rock at from 75 to 123 feet. The actual cost of sinking 170 linear feet of shaft at the mouths of one of the canyons of a southern California river, in an attempt to determine bed rock, was $35.87 per foot, the depths in this case varying from 15 to 30 feet, and the material through which the shafts were sunk consisting of sand and bowlders. This included the labor of building 700 feet of flume, but not the cost of the lumber, which was furnished by the company for all work. There was pumped from these shafts with a 100-horsepower boiler and engines over 100,000 gallons per hour, and yet the water could not be kept down, and the deepest shaft had finally to be abandoned before bed rock was reached.

The best estimate that could be obtained of the cost of sinking by means of the diamond core drills, as furnished by San Francisco contractors, was $12.69 per linear foot, 400 feet to be sunk, but they would not offer a bid even on these figures.

The following letter from Mr. T. F. Richardson, department engineer, dam and aqueduct department, metropolitan water board, of Boston, is of interest as bearing on this subject:

We had two diamond drills, one manufactured by the M. C. Bullock Manufacturing Company, of Chicago, called the Badger drill. This drill was intended for prospecting in tunnels, but was fitted up especially for us for surface work. This machine cost us $900, which included one set of diamonds worth about $200, and the necessary fittings to put down a 1⅛-inch hole about 200 feet.

Our second machine was bought from the Sullivan Machinery Company, of Claremont, New Hampshire, and was called "S–510." This cost was $1,132.80, but no diamonds were included. The two machines were fitted for and were capable of doing about the same amount of work, but the net cost of the Sullivan machine was over $400 more than that of the Bullock machine.

Our work here was very difficult, as the bottom of our gorge was blocked up with large bowlders, and we found it necessary to use several sizes of bits, namely, 1⅛-inch, 1⅜-inch, 1⅝-inch. We also had to fit up so as to be able to put down 1¼-inch casing, using diamond bits to bore it down, the purpose of the casing being to bore through bowlders and gravel, so as to be able to work a 1⅛-inch bit inside of it. Altogether we had two quite complete outfits for doing all kinds of work up to 1⅝-inch bits.

The repairs necessary to the machines were not very large, the principal cost of repairs being for new bit blanks and for core lifters; but in order to do the work successfully it is necessary to have quite a number of appliances outside of the actual machines, and these cost considerable money. Our total outlay for machines was $2,625. In addition to this we spent $3,873 for diamonds, but we have at the present time about $700 worth of diamonds on hand, leaving the net cost of the diamonds about $3,173.

When we started in on our diamond-drill work the cost of diamonds was $19 per carat; but at the time we finished the cost of diamonds had risen to $36 per carat, and I believe the price is about $36 at the present time (August, 1898).

The total amount which we drilled was 2,814 feet, the deepest hole being 286 feet deep, and the average depths of holes about 60 feet. The amount accomplished per day was from 0 to 32 feet, the average amount being probably about 10 or 12 feet per day.

The cost of drilling varies very largely, both with the hardness of the rock and the condition of the rock as to being seamy.

Following is the cost of labor, diamonds, and coal for drilling, principally with 1½-inch bits, through three different kinds of rock:

Drilling 324.2 feet of rather hard, tough diorite rock:

Labor	$241.25
Diamonds	74.30
Coal	17.50
Total	433.05
Cost per foot	1.34

(86.6 feet of this was drilled with 1⅝-inch bit, and 237.6 feet was drilled with 1½-inch bit.)

Drilling 150.7 feet of very hard syenite rock:

Labor	158.00
Diamonds	298.69
Coal	10.50
Total	467.19
Cost per foot	3.10

(Size of drill, 1½ inches.)

Drilling 286.1 feet of soft schist rock:

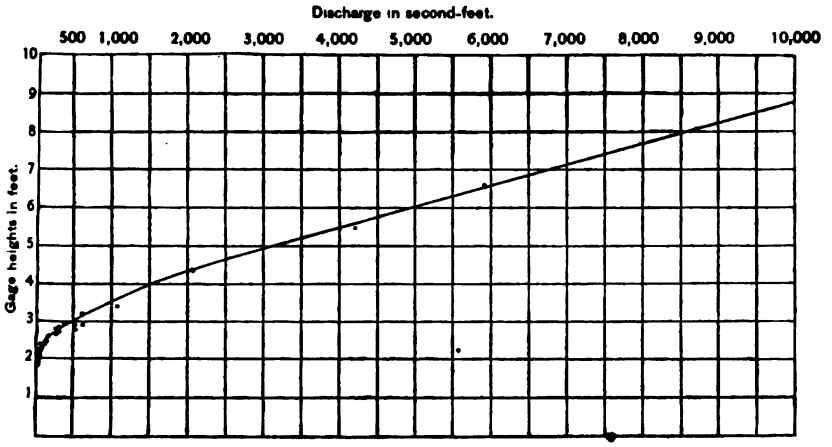
Labor	190.00
Diamonds	87.75
Coal	11.50
Total	289.25
Cost per foot	1.01

(Size of drill, 1½ inches.)

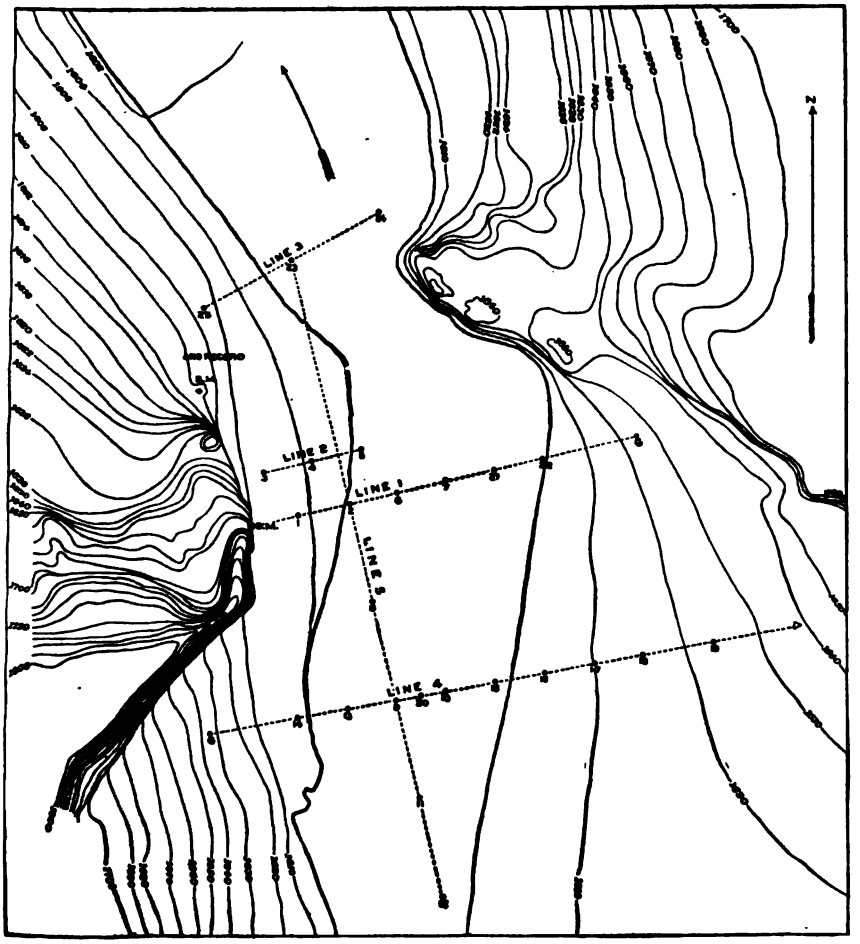
You will notice that there is a large variation in the cost of drilling through different kinds of rock. The costs as given do not include more or less lost time. and the depreciation on diamonds due to their being of smaller size after being used. Finally they get so small as to be valueless. Depreciation of plant is also not included.

Regarding the best size of hole for prospecting purposes, this depends largely on the work which you have in hand. If I were fitting up for similar work to what we did here, and only expected to fit up one size of hole, I should fit up probably for 1⅝-inch bit.

When I speak of 1⅝-inch bits, I mean bits that give cores of about this size, though generally the cores are somewhat smaller than the sizes noted.



A. RATING CURVE FOR GILA RIVER AT THE BUTTES. USED DURING PERIOD FROM JULY 11 TO AUGUST 10, 1899.



B. LOCATION OF BORINGS AT BUTTES DAM SITE.

Diamond-drill work is expensive amusement at the best, and I think you will be safe to conclude, whether you do the work yourself, buying the machines, or do it by contract, that the cost will be somewhere in the neighborhood of three or four dollars per running foot.

It was decided to attempt to explore for bed rock by means of diamond core drills, and, through Mr. Arthur P. Davis, who was in charge of the work, machines for this purpose were obtained from the Nicaragua Canal Commission. These machines had been used in Nicaragua in exploring for bed rock along the route of the proposed canal, and had done efficient service. Two foremen, Mr. P. Tierney and Mr. T. J. H. Archambault, were employed to run the machines. These men had previously used them in Nicaragua, and were entirely competent to do the work efficiently. The machinery is in two distinct parts: First, a pile-driving apparatus for putting pipe or casing down through quicksand or earth; the pipe is afterwards washed out, and inside of it the shaft with the diamond bits is operated. The second part is the drilling apparatus proper. The machinery is very light, and made so that it can be knocked down to weights that will admit of the sections being carried on the backs of men. The hammer is in sections and can be increased or lessened in weight. The bottom section is cored out and filled with wood, so that the blow of the hammer will not abrade the head of the pipe. It is raised by means of a hand winding drum, and is tripped when it reaches the tops of the guides, and falls upon the pipe. The maximum lift is 11½ feet and the maximum weight 190 pounds. A tool-steel head is screwed into the top of the drive pipe for the hammer to fall upon.

The pipe is shod at its lower end with a tool-steel shoe, which is thicker and heavier than the pipe, but equal to it in interior diameter. The size of the pipe used is 3½-inch, 2½-inch, and 2-inch extra heavy screw pipe, with extra heavy couplings which have beveled corners. The smaller diameter pipe is in each case made to fit into the larger diameter if required. It, however, requires a special make of 2½-inch pipe to go inside of the 3½-inch pipe. The pipe is driven through the sand and gravel until bed rock is reached. This is indicated by the refusal of the pipe to go any farther under driving. The pipe is cut in 5-foot sections, and as it is driven into the ground new sections are put on until the desired length is reached. When the drive pipe has reached bed rock, what is known as a chopping bit, which is a bit with openings for water to flow through its point, and to which is screwed a ¾-inch pipe, is worked into the drive pipe. The top of this ¾-inch pipe is connected with a small, double-action hand force pump by a hose.

The chopping bit is churned around in the sand which is inside of the drive pipe, and the water which is under pressure is discharged through the point of the chopping bit, and floats the loosened sand out over the top of the drive pipe. In this manner a hole can be readily cleaned to depths as great as 130 feet of sand and small gravel.

The diamond-drilling machinery is put to work when the drive pipe is cleaned out, and it is possible that it may demonstrate that, instead of being on bed rock, the drive pipe has stopped upon a bowlder. As soon as the diamond bit passes through a bowlder it drops, which is an indication that bed rock has not been reached. The diamond drill is then drawn and four or five sticks of giant powder are lowered through the pipe to the bowlder. The drive pipe is then pulled up four or five feet, and the powder discharged by means of an electric firing battery. This shatters the rock, and the drive pipe may then be forced through the splintered bowlder. In this manner pipe of these varying diameters were driven to bed rock at five different dam sites, and at every location successful results were obtained.

COST OF OPERATING.

The diamond-drilling machine used was built by the American Diamond Rock Drill Company, of 123 Liberty street, New York. One-inch bits were usually employed. The diamond drilling machinery is shown on Pls. I and VII, *A*. The drill is operated by hand power, six men being economically employed on this work, as well as on the driving of the pipe. The machine is capable of going 200 feet into the rock, and will make from 6 to 8 feet a day in hard rock, and from 10 to 15 feet a day in softer rock. The cost of the machinery complete is approximately $1,000, including two bits, which are worth about $200 each, set with six diamonds each. The diamonds are known as black diamonds, and should weigh approximately 1 carat each. Two machines were used on work in southern Arizona. There was paid for the pipe $590, including tools and fittings, delivered in Arizona; $100 of this amount being freight from New York. This would make a total cost of outfit complete of $1,590.

Cost of operation per month of bed-rock exploration.

Foreman	$150.00	
6 laborers, at $1.50 per day, 28 days	234.00	
1 cook	45.00	
		$429.00
240 rations, at 60 cents		144.00
Total repairs, pipe and lumber for one party for ten months	500.00	
Total commissary charges for team, feed, etc	350.00	
Total moving	670.00	
Total sundry incidentals	200.00	
Total supervision	350.00	
Total, ten months	2,070.00	
Sundry expenses per month		230.00
Total cost per month		803.00
Ten months, at $803		8,030.00
Total number of feet sunk		3,254.3
Total cost		$8,030.00
Cost per foot		2.46
Cost per hole, 7,227÷52		154.42

U. S. GEOLOGICAL SURVEY

If the original cost of machinery be distributed over this work, the results would be as follows:

Operation	$8,030.00
Machinery	1,600.00
Total cost	9,630.00

Or average cost per foot, $2.86.

Both machines are still in good repair after having been used in Nicaragua and in various localities in Arizona and California.

The total depths penetrated in all materials at the various dam sites are:

	Covering.	Rock.	Total.
The Buttes	1,621.2	196.0	1,817.2
Queen Creek	357.8	55.6	413.4
Riverside	729.8	40.2	770.0
Dikes	80.0	0.0	80.0
San Carlos	143.2	30.4	173.6
Total	2,932.0	322.2	3,254.2

The work at the Buttes at the last three holes and at the Dikes was very greatly delayed, owing to the loss of the original drive pipe by breaking beneath the surface. The pipe that was next obtained broke continually under the hammer, and a month's time of one party was lost by these interruptions. The expense of this work is included in the above estimate. Owing to the long move by teams of the outfit to San Carlos dam site and the constant interruption by floods of the work at that point and the consequent small amount of driving done there (173.6 feet), the cost of that portion of the work was about $6 per linear foot. If San Carlos is not included in the estimate, the average cost per foot for the remaining portion of the work would be reduced about 10 cents.

The advantages of this class of work over the shaft method are manifest. It is probable that not over five or six shafts could have been put down with the total funds available in case that method was practiced, and it is problematical even then if it could have been accomplished. By the drilling method employed the location of bed rock is not only determined, but an actual sample has been brought up, which can be tested for specific gravity, crushing strength, texture, quality, or in any other manner desired. The work was entirely successful, except at San Carlos, where the floods became so violent during the month of August, 1899, that the machinery could not be kept

standing in the river, and but two holes reached and penetrated the bed rock.

BUTTES RESERVOIR.

EXPLORATION FOR FOUNDATIONS OF DAM.

As recommended in the report by Mr. Arthur P. Davis, made in 1896, explorations have been made to determine the depth of bed rock and the quality of the rock at the Buttes dam site. By this survey of 1899 the diamond core drill demonstrated the fact that the soundings which were made by rods and which are described in the report above mentioned were misleading. There is proved to be a limit beyond which it is impossible to drive rods in gravel and sand, and this limit, which is found to be approximately 60 feet in the material composing the bed of the Gila, prevented the correct determination of bed rock in 1896 by the rod method. Twenty-four holes were put down by the diamond core drill at various points in the canyon at the Buttes, the effort having been made to find some point where the bed rock would be shallow. The following table shows the depth and character of the bed rock determined.

Log of borings at the Buttes dam site, Gila River, Arizona.

Line No.	Hole No.	Depth to bed rock.	Depth to bottom of boring.	Depth drilled in rock.	Correct elevation of surface June, 1899.	Correct elevation of bed rock.	Bed-rock elevations reduced to datum of contour map (= +13.38).
		Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
3	23	57.0	63.0	6.0	1,589.00	1,532.00	1,545.38
3	24	46.4	53.5	7.1	1,589.00	1,542.60	1,555.98
2	3	21.4	28.3	6.9	1,591.52	1,570.22	1,583.60
2	4	70.0	77.5	7.5	1,589.00	1,519.00	1,532.38
2	5	122.6	132.0	9.4	1,589.00	1,466.40	1,479.78
1	1	65.0	82.0	17.0	1,589.00	1,524.00	1,537.38
1	2	80.0	95.0	15.0	1,589.00	1,509.00	1,522.38
1	6	105.0	112.3	7.3	1,589.00	1,484.00	1,497.38
1	7	70.0	79.0	9.0	1,589.00	1,519.00	1,532.38
1	21	53.0	64.0	11.0	1,589.00	1,536.00	1,549.38
1	22	13.5	20.2	6.7	1,589.00	1,575.50	1,588.88
4	14	8.0	12.6	4.6	1,589.00	1,581.00	1,594.38
4	13	62.1	68.9	6.8	1,589.00	1,526.90	1,540.28
4	9	71.4	78.7	7.3	1,589.00	1,517.60	1,530.98
4	20	68.6	74.5	5.9	1,589.00	1,520.40	1,533.78
4	10	66.8	84.1	17.3	1,589.00	1,522.20	1,535.58
4	15	64.0	70.7	6.7	1,589.00	1,525.00	1,538.38
4	16	62.7	70.7	8.0	1,594.00	1,532.10	1,545.48
4	17	70.0	79.0	9.0	1,596.62	1,526.62	1,540.00
4	18	68.7	79.1	11.4	1,602.12	1,533.42	1,546.80
4	19	26.4	34.0	7.6	1,610.62	1,584.22	1,597.60
5	8	78.0	95.0	17.0	1,589.00	1,511.00	1,524.38
5	11	82.0	94.0	12.0	1,589.00	1,507.00	1,520.38
5	12	(*a*)	----------	----------	----------	----------	----------
	25	(*b*)	----------	----------	----------	----------	----------

a Not reached at 77 feet. *b* Not reached at 101 feet.

The contour maps of the Buttes dam and reservoir sites, which were surveyed in 1896, were based upon a datum which was taken from the local records of the Florence canal. Subsequently a line of levels

A RESULT OF QUARRY TEST AT CLIFF ON RIGHT BANK BELOW BUTTES DAM SITE.

B. DAM SITE ON QUEEN CREEK.

was run from the railroad station of Casa Grande, on the Southern Pacific line, to the Buttes dam site, and upon this datum the topographic map of the irrigable lands in the vicinity of Florence was made. Upon this corrected datum the canal surveys were made, and a bench mark was established at the Buttes dam site. The elevations given on the large contour map of the dam site, which is on a scale of 50 feet to the inch, are based upon the first elevation of Florence canal datum, which the subsequent levels show to have been 13.38 feet too high. The elevations given on the plans and sections of the Buttes dam correspond to the elevations of the contour maps of the dam and reservoir surveys and do not correspond with corrected elevations. The elevations given in the above table are both the corrected elevations and the elevations on the same datum as that used for the contour map and plans of dam.

The holes whose surface elevation is given as 1,589 are those bored in the immediate bed of the stream. Those of higher elevations started on the alluvial benches above low-water level on either side.

QUALITY OF BED ROCK.

At each one of these points a core was brought up showing the quality of the bed rock. The following table is a description of the cores obtained at the Buttes:

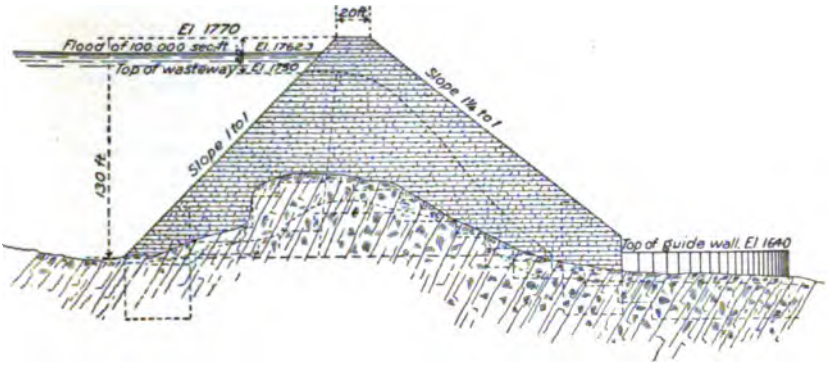
Cores obtained from borings at the Buttes.

Number of hole.	Depth drilled in rock.	Length of core obtained.	Quality of rock.
	Feet.	*Feet.*	
23	6.0	4.00	Pearlite.
24	7.1	4.40	Pearlite and ash.
3	6.9	2.40	Pearlite, very solid and brittle.
4	7.5	1.80	Volcanic ash.
5	9.4	4.25	Volcanic ash, badly pitted.
1	17.0	9.00	Pearlite, mingled with ash.
2	15.0	1.40	Porous ash.
6	7.3	2.40	Volcanic ash, badly pitted.
7	9.0	5.30	Hard ash.
21	11.0	2.40	Hard, volcanic ash.
22	6.7	5.00	Pearlite.
14	4.6	3.00	Volcanic ash.
13	6.8	1.80	Volcanic ash, very porous.
9	7.3	5.20	Blended ash and pearlite.
20	5.9	4.50	Volcanic ash.
10	17.3	4.10	Volcanic ash, quite hard, but badly pitted.
15	6.7	.85	Very porous volcanic ash.
16	8.0	5.00	Volcanic ash.
17	9.0	2.50	Do.
18	11.4	1.66	Do.
19	7.6	4.00	Do.
8	17.0	2.25	Do. very porous.
11	12.0	5.00	Hard, volcanic ash.
12	----------	----------	Bed rock not reached; hard pan at 40 feet.
25	----------	----------	Bed rock not reached.
	216.5	81.71	

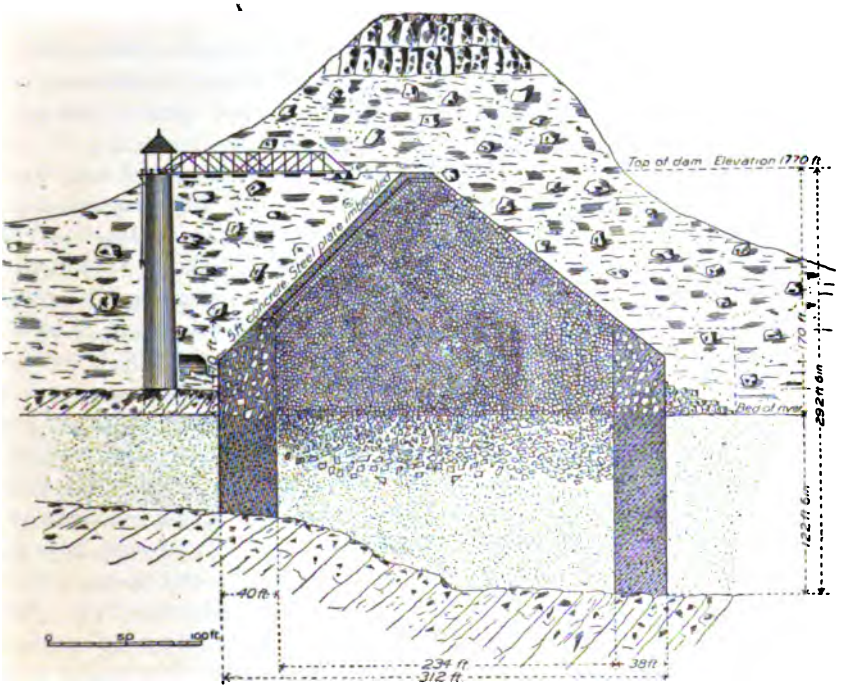
The location of these borings is shown on Pl. VIII, *B*, these being arranged in five different rows. At the relative location of each hole a figure has been placed on the diagram corresponding to the number given in the above tables. The point marked "B. M." shows the position of the bronze bench mark set in the face of the cliff. It is the initial point of the survey for the location of the borings. At the point marked "G" is a steel gad seven-eighths of an inch in diameter, set in the rock.

In taking out many of the cores it was found that, while the drill had entered the rock for distances of from 6 to 12 feet, the cores extracted were very much less in length, owing to the crumbling of the rock as it was cut. The bed rock varies between a volcanic glass, or obsidian called pearlite, and a porous ash. The obsidian is exceedingly hard, but the ashy material is full of holes, quite soft, being readily cut with a knife, and of a crumbling nature. A total depth of 216.5 feet was bored into the bed rock, and but 81.71 feet of core obtained therefrom, or only 38 per cent of the total length of the core was of such material as would permit of its extraction from the holes. It is but fair to assume that the remaining 62 per cent is of a poorer class of material than that which was extracted.

The following table gives crushing tests which were made in the laboratory of the city engineer's office at Los Angeles, California. The crushing limit of the machine used is 2,565 pounds per square inch. This would be equivalent to 184.7 tons per square foot. A good many of the samples could not be crushed on the machine, but it has been considered that all rock which could not be crushed with this pressure is reliable and could be accepted as a satisfactory foundation material. The poorest rock is undoubtedly that portion of the core which has gone to pieces under the action of the diamond drill, and which could not be extracted. Tests were obtained from the samples as low as 79.5 tons per square foot. It may therefore be assumed that the tests made are of the better class of rock, and that if any of the samples indicate a weakness below the limit of safety it would justify the abandonment of the bed rock as a proper foundation for a cement-masonry dam. The assumed maximum height of the dam being 170 feet above the bed of the stream, and 123 feet to bed rock below the same, or a total height of 293 feet, the base would have to be made so wide in order to keep the pressure at the outside toe within safe limits that the cost would be prohibitory. Some of the cores having crushed with 80 tons pressure per square foot, a rubble-masonry dam is abandoned for this site. Crushing tests were made by J. W. Robinette and S. G. Bennett. Specimens were 1 inch long and 1 inch in diameter.



A. ELEVATION OF END WALL OF BUTTES DAM.



B. MAXIMUM CROSS SECTION OF PROPOSED DAM AT THE BUTTES, ARIZONA.

Specific gravity, weight per cubic foot, and crushing tests of diamond-drill core from bed rock at the Buttes, Arizona.

No. of specimen.	Weight in air.	Weight in water.	Loss.	Specific gravity.	Weight per cubic foot.	Crushing test, pounds per cubic inch.	Crushing test, tons per cubic foot.	Remarks.
	Ounces.	*Ounces.*	*Ounces.*					
1	1.10	0.60	0.50	1.86	116.4	2,565+	184.7+	Stood 2,000 pounds.
2	0.75	0.30	0.45	1.66	103.0	1,035	79.5	Crushed at 807 pounds.
3	1.30	0.75	0.55	2.39	149.5	2,565+	184.7+	Stood 2,000 pounds.
4	0.95	0.45	0.50	1.98	120.5	2,565+	184.7+	Do.
5	0.90	0.47	0.43	1.79	112.0	2,565+	184.7+	Do.
6	0.82	0.40	0.42	1.95	122.0	2,469	177.0	Crushed at 1,926 pounds.
7	0.70	0.30	0.40	1.75	109.0	2,288	164.7	Crushed at 1,785 pounds.
8	0.85	0.40	0.45	1.86	116.4	2,565	184.7+	Stood 2,000 pounds, but developed longitudinal crack after being taken out of testing machine.
9	0.90	0.45	0.45	2.0	125.0	2,088	150.0	Crushed at 1,629 pounds.
10	0.95	0.46	0.49	1.855	116.0	2,565+	184.7+	Stood 2,000 pounds.
11	0.86	0.45	0.41	2.10	131.0	2,077	149.5	Crushed at 1,620 pounds.

QUARRY TESTS.

The rock at the Buttes appearing to be of a questionable quality for concrete or rubble masonry work, it was decided to be necessary to make quarry tests in order to determine accurately its nature. Mr. D. Anderson, mason and quarryman, of Los Angeles, California, made the following quarry tests:

At the first cliff on the right bank below the dam site at the Buttes, 12 feet back from the edge, two holes were put down, 5 feet 6 inches and 3 feet in depth, respectively. This location is marked by the figure 1 on contour map of the Buttes dam site (Pl. IX). Eight sticks of giant powder started the rock and one 25-pound keg of black powder pushed it off. The result was one 10-ton rock, one 2-ton rock, and numerous small rocks ranging from 25 to 500 pounds. The rock is a pearlite, heavy, close grained, and fairly free from seams. It dropped from 150 to 175 feet, to the foot of the cliff, falling partly on earth and partly on rock, without badly shattering it. It drills easily, two strikers going 18 inches an hour with 1¼-inch bit, but large quantities of powder are required to start the rock.

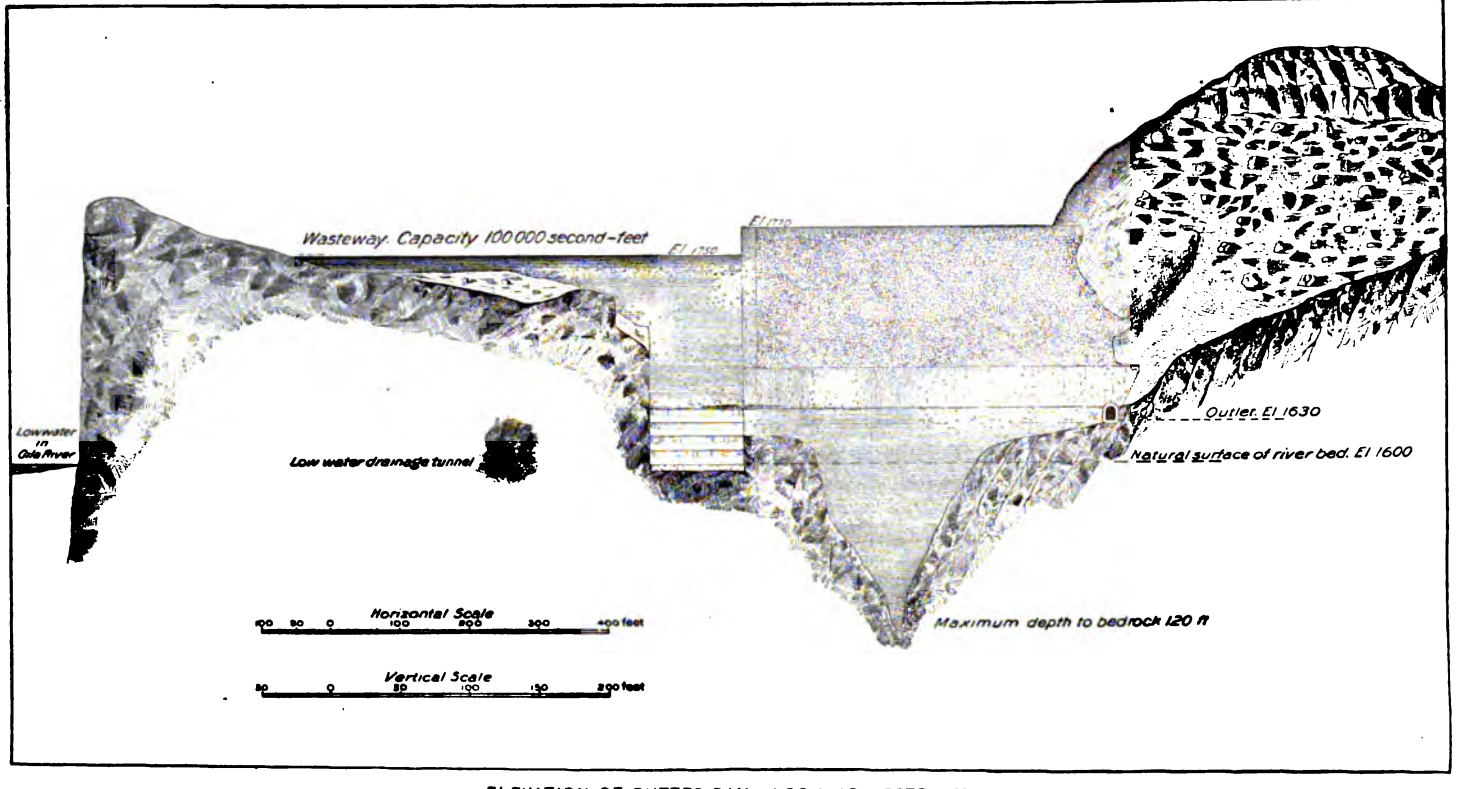
The second test, at figure 2 on Pl. IX, was on east face of same cliff. Five-foot holes were put down in a step series, 2½ sticks of giant powder being used to spring each. Afterwards holes 2½ feet deep were filled with black powder, 3 kegs being used in five holes. The result is hard to estimate—probably 100 to 200 tons of rock were thrown down. There were one 2-ton, two 1-ton, and about twenty quarter-ton rocks. The large pieces are pearlite; the smaller ones are a hard ashy rock.

The point west of the left spillway, at figure 3 on Pl. IX, was opened on June 10, 1899, and a hole was put down 4 feet 4 inches and four sticks of giant powder were exploded therein. The rock exposed seems to be a partly solidified pearlite, light and brittle. Soft streaks and spots are found throughout the mass, and it does not seem suited either in weight or structure to bear a rubble-masonry dam. About one-third of it is a white-colored ash and two-thirds is a gray, hard substance, brittle and light. The ashy material cuts readily with a knife, while the gray is hard to scratch. These white spots are often eroded by wind action when occurring at the surface, holes being thus formed as large as 2 feet in diameter.

At a point 100 feet northeast of the left-hand spillway (bench mark), at figure 4 on Pl. IX, a hole 4 feet 6 inches was put down on June 7 and five sticks of giant powder were used (three and one-half sticks to the pound). The rock is similar to that previously noted, but harder and ashy white, and usually resists a knife, but there are spots that cut like chalk. In the lower portion of the spillway, at figure 5 on Pl. IX, a blast was put off which showed that the material is softer and more fragile in the spillway than elsewhere and of a very questionable nature for cement-masonry work. On the southwest end of the low butte, at the left dam abutment, at figure 6 on Pl. IX, a hole 6 feet deep was put down June 10, and three sticks of giant powder were used to spring it. Twelve pounds of black powder were then used to throw down the rock. This revealed a high-grade, heavy, volcanic glass, resembling the first, tested across the river. Overlying the pearlite is a streak of ashy gray, but harder and darker than at the spillway.

The prevailing rock at the dam site is an indurated ash. It is found in the cliffs of the left bank, east of the spillway and at the proposed upper portal of the tunnel on the right bank. The lighter ash is liable to crush and erode. Probably enough of the pearlite could be selected to build a concrete or rubble dam, but it would be a matter of selection, and much of the lighter rock would have to be moved to get at the better rock. This probably would be 50 per cent of the mass. The rock in the left-hand spillway probably could not be put in a concrete dam. It could, however, be used for a core of a rock-fill dam.

On the first cliff south of the dam site, on the right bank, facing the river, two large blasts were fired at the first projecting point, at figure 7 on Pl. IX. Three holes were put down, 14 feet, 15 feet, and 16 feet deep, 18 feet back from the face of the cliff. The rock was hard and cut coarse. Three men could go down 10 inches per hour with a churn drill. Four pounds of giant powder were used to the hole. This sprung the cliff from one side to the other, about 30 feet deep. The crack was then charged with black powder, 3½ kegs being put down to each hole. The powder in hole No. 2 went into a crevice and did



ELEVATION OF BUTTES DAM. LOOKING UPSTREAM.

little good. The entire point sprung, but did not fall, but around the edge was revealed pearlite of a good quality. There were six men in all, including blacksmith and helper, who worked fifty-three hours at this point. The rock dips into the cliff, so that while the ledge was pushed off as much as 5 feet it did not fall.

On June 24 about 50 pounds of giant powder was placed in the key of this mass and shot. This brought it down with the following approximate results: Length of fallen mass, 80 feet; height above sand, 10 feet; depth in sand, 5 feet; width, 30 feet. This is about 440 cubic yards of loose rock. Pl. X, *A*, gives a view of this test. There were approximately one 10-ton rock, ten 5-ton rocks, and thirty 1-ton rocks. The mass ranges from stone that would pass through a 3-inch ring to rocks 150 pounds in weight. It is of a mixed ashy structure, and not solidified glass. There are numerous flow lines or fissures which are contorted, and the rock has gone to pieces badly. This rock fell 180 feet upon the sandy river bed. The pearlite is not so pure as was indicated by the first test; it seems to be stratified, and changes often from pearlite into an ash, or the reverse. Numerous chips knocked off the corners of base of this cliff with a hammer show it to be a hard, volcanic substance, such as is frequently penetrated by the diamond drill as bed rock.

At the west end of the first bluff below dam site on right bank at figure 8 on Pl. X five men worked fifty-three hours. The rock is softer than that at the middle of bluff, shown in last tests. It cuts very easily, but the drill holes clean hard and the dust from cutting forms paste when mixed with water. The average rate of progress with the churn drill is 10 feet an hour. Three holes, 8 feet apart, were put down approximately 16 feet in depth and 18 feet from the face of the cliff. Four pounds of giant powder were used to the hole, and the cliff was cracked across the point. The crack was opened by a second charge, consisting of 2 pounds of giant and 5 pounds of black powder to the hole. This resulted in a crack 2 inches wide, extending 38 feet. There seems to have been an error in judgment on the part of the quarryman in springing the rock too much before using the black powder, which expended its energy, in a large part, through the fissures of the rock. This crack was then charged with ten kegs of black powder, and a portion of the cliff in front of one of the holes was thrown off, knocking down about 300 tons of rock. The other portions on the cliff were not thrown off, but sufficient material was revealed to show the nature of the rock. In this, as in the former case, the rock fell 180 feet. There were from 8 to 10 large rocks displaced, ranging from 6 to 8 tons in weight, but a large portion of the fragments range from 100 to 200 pounds, while much of the rock, possibly 25 per cent, is in pieces weighing less than 50 pounds. There is a large amount of rock buried in the sand. This rock is a reddish or fused ash, rather light and brittle, but hard, and with

many seams. It ranges in a very intricate way from glass to ash, and back again to volcanic glass. Fully 66 per cent is glass. At a point 25 feet south a smaller blast showed pure glassy pearlite, which falls without shattering. The first grade pearlite is rather rare and can not be obtained in large quantities. The ashy material is the prevailing rock and is of inferior grade for construction purposes.

A block of the poorer class of the volcanic ash from the spillway on the left bank, containing soft spots of light, chalk-like material, was immersed in water in June, and continued under water until the first of October, over three months. At the expiration of this time the softer portions of the rock indicated, if anything, a hardening, but still could be cut with a knife. It would be between 2 and 3 in the scale of hardness.

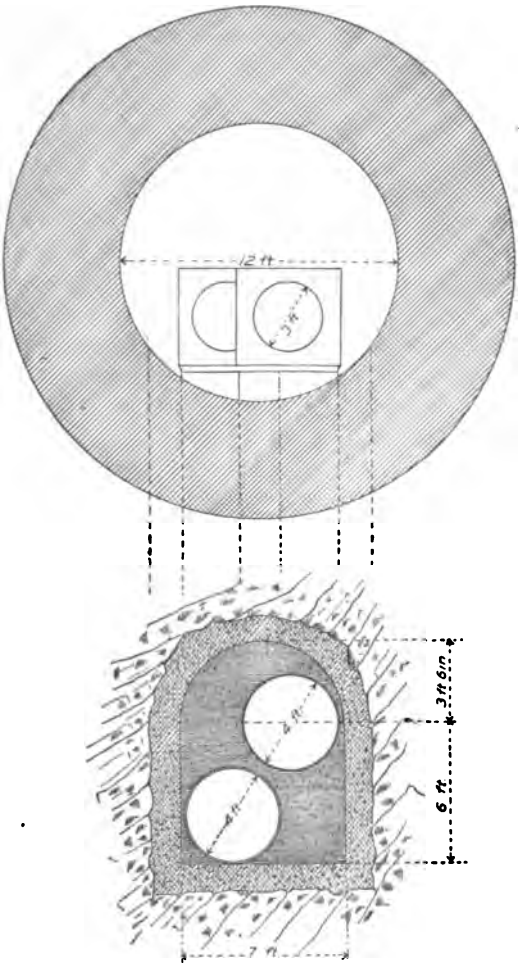
In conclusion, it may be stated that it would be difficult to select a sufficient amount of rock of first-class quality for concrete work or rubble masonry to build a dam of that type of the size required from bed rock to a line 170 feet above the bed of the stream, a total height of 223 feet, without large expense. The rock at the Buttes would be suitable for the construction of a rock-fill dam, the poorer class rock being placed in the center of the dam and selected rock on the two faces and at the spillway weir on the right bank.

It is probable that the dam could be most economically constructed from quarries at the cliffs on the right bank of the canyon below the dam, tramways being used for delivering the rock to the structure. The tramways would vary in length from 500 to 1,000 feet. If cableways were used they could not properly be placed on lines which would be near or parallel to the axis of the dam, and if they were not so located it would require a double system of cables for handling the rock, one to bring it from the quarries to the dam site, and a second set to distribute the rock at the dam.

The conclusion reached from the investigation of bed rock with the diamond core drills and from the quarry tests leads to the adoption of a rock-fill dam for the Buttes as the only class of structure which it would be feasible to build with the material available and on the foundation there existing. For this reason the estimate of cost has been made solely upon this type of dam.

TYPE OF DAM ADOPTED.

It is evident that the desired type of dam must have a very broad base, reducing to a minimum the pressure per square foot on each portion of its foundations. A dam with this breadth of base would call for a heavy expenditure for the excavation to bed rock if the entire section were taken out. In order to be stable and to retain the water impounded above it, the dam must have an impervious connection with bed rock. The style of dam selected (Pl. XI, *B*) is of the rock-fill type, with concrete retaining walls and with a concrete spillway weir



CROSS SECTIONS OF TOWER AND OUTLET TUNNEL OF BUTTES DAM.

on the right side. It is proposed to put a wall down to bed rock at the upper toe of the dam sufficient in thickness to withstand the pressure of water against its upper face when excavations are made behind it. At the lower toe of the dam it is proposed that a similar wall shall be put down to bed rock in order to protect the structure from erosion from the spillway on the right bank and to retain the inclosed mass of sand and gravel as a foundation for the riprap or dry-laid rock.

The section and rear view, looking upstream, of this proposed structure are shown on Pls. XI and XII.

Between these two walls there will be held a mass of sand, gravel, and bowlders, which constitute the natural bed of the river and which will not be excavated. The distance between these two walls is 234 feet. It is proposed that they shall be carried up above the bed of the stream to an elevation of 58 feet on the lower wall and 63 feet on the upper wall. Loose rock will be deposited between them as they are raised in elevation, and the river will be allowed to flow a portion of the time over the masonry walls onto the mass of rubble lying on the sandy bed of the stream. The churning action which will result therefrom will permit the heavy rock to settle into the bed of the river, it being desirable to have this take place as much as possible. In case this does not occur naturally, it is proposed to pump water onto this rock and force a settlement in that manner. The rock forming this portion of the dam will be as large as can be handled.

An outlet tunnel will be constructed through the point of rocks at the right abutment of the dam at the lowest possible elevation, as shown on Pl. XII. This tunnel (Pl. XIV, *A*) will be 15 feet high, 10 feet wide, and 139 square feet in area. It will discharge under pressure and with high velocity and will carry the river at all stages of low water and in ordinary floods. It will be about 1,000 feet in length and have over 1,000 second-feet capacity. This tunnel will permit, during all usual occasions, of the regulation of the river as may be desired during construction. Afterwards it can be used to carry off flood waters, and it will not ordinarily supply water for the irrigation canals. On the left bank the delivery tunnel (see Pl. XII) will be located 30 feet above the natural bed of the stream and will discharge, if desirable, into the main irrigation and power conduit.

A serious problem in connection with the construction of this dam will be the handling of the great floods which possibly may occur in the river during its erection. If such a flood should occur during construction, and be permitted to pass over the dam while it is in an incomplete condition, the loose rocks would probably give way under the violence of the current and destroy the work already performed. There would then be added to the flood the volume of water resulting from the bursting of the reservoir, and disaster would follow not only to the structure itself, but to settlements and towns along the Gila River below the dam. In order to prevent this the

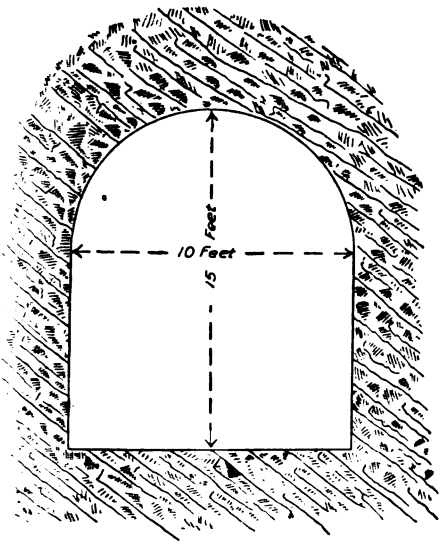
two masonry retaining walls (Pl. XI, *B*) are carried above the bed of the river to the elevations named. If when these walls have reached their maximum height and the intervening space is filled with riprap a flood of great magnitude should pass over the dam the structure would stand, the loose rock being held between the two retaining walls would settle down into the sand bed between them. This would be exactly what would be desired. An examination of Pls. V, *A*, and XII shows that the bed rock has a very flat slope on the right abutment. It is proposed that a wall (Pl. XI, *A*) should be built from this bed rock, as shown on Pl. XII, 20 feet in thickness, as a retaining wall for the right end of the loose-rock portion of the dam, connecting the upper and lower toe walls. The purpose of this wall is to retain the loose rock and to protect it against the attacks of floods. This end wall will be made of concrete, and an excessive thickness will not be necessary, because it will be reenforced by the secondary rubble-masonry weir to its right.

A cut (shown by the crosshatching on Pl. IX) will be made into the sloping rock at the right abutment down to an elevation of 40 feet above the natural surface of the river bed and to a width of 100 feet at the bottom. This cut would be carrying water at a depth of 30 feet when the water reached the elevation of the top of the higher toe wall of the dam, and a corresponding head on the large tunnel of 70 feet would then exist. This would probably carry any ordinary flood which might occur in the river.

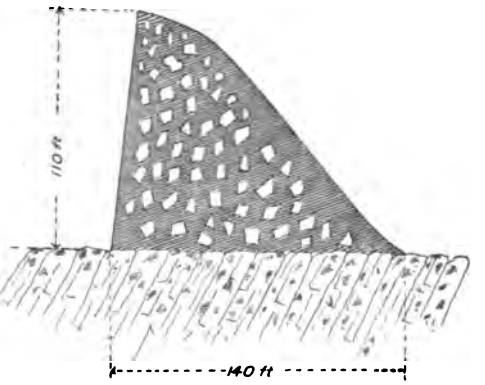
The effort should be made during the first year of construction to complete the two retaining walls from the bed rock to the surface of the stream. During the second season these walls can be completed and as much of the rock-fill dam as possible constructed. In the third year the rock-fill dam should be completed and the concrete weir constructed.

As the work on the rock-fill portion of the dam advances and its crest rises in elevation, the construction of the concrete weir on the right abutment, which is to act as the spillway for the structure, can be begun and carried on with the remaining portion of the work. The two faces of the central dam are to be laid up by hand in dry wall, and the slopes which have been accepted for the dam are practically the natural angles of repose, so that little tendency to slide is likely to exist.

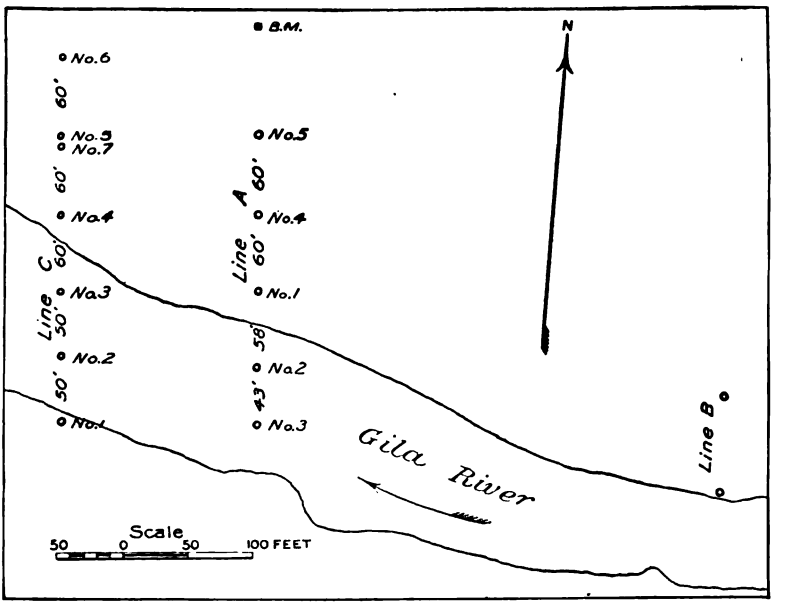
In order to make this structure water-tight it is proposed to cover the upper face with an apron of concrete 5 feet in thickness, which will be connected with the upper toe wall and the two abutments of the dam. In this apron of concrete a continuous riveted steel plate will be embedded 4 feet beneath the water face of the dam and 1 foot from the dry-laid rock wall. Angle irons will be riveted horizontally and vertically on both sides for the purpose of stiffening the plate and insuring a better connection with the concrete. The steel plate



A. CROSS SECTION OF LOW-WATER TUNNEL, BUTTES DAM.



B. MAXIMUM CROSS SECTION OF WASTEWAY, BUTTES DAM.



C. LOCATION OF BORINGS AT RIVERSIDE DAM.

will make the dam additionally impervious and lend strength to the concrete.

Gates will be placed at the upper portal of the flood tunnel and will be operated from the surface of the ground. The gates for the tunnel which is to discharge into the irrigation conduit will be operated from a tower (Pl. XIII)

Quarry tests were made of the spillway on the left bank, and the rock was found to be of such nature that it would not stand the erosion of a great flood. It is of a volcanic, ashy character, porous in spots, light in weight, and portions of it can be readily whittled with a knife. A flood approaching 100,000 cubic feet per second passing over this material would tear it to pieces, it is believed, and erode great channels. It would be exceedingly expensive to cover this spillway with concrete so as to protect it or to build a series of checks to mitigate the erosive action of the water.

On the right abutment, however, the rock is of a harder nature. It is, to a large extent, an obsidian, or pearlite, and it is believed that it will resist erosion. This bed rock on the right abutment is practically at the surface from an elevation of 20 feet or more above the bed of the stream. A concrete weir of the section shown on Pl. XIV, *B*, will be constructed on this abutment, the elevation of the top being 20 feet lower than the top of the loose rock dam, and of a length of approximately 650 feet. Any flood occurring will pass over this portion of the dam only. This concrete weir will be built into the excavation which was made for the flood waters and connected with the retaining wall at the right end of the rock-fill dam. Its section will be such that any flood may pass over it without injuring it. The dam will be protected on its flank and at its lower toe with solid walls of concrete, and the floods passing over the weir will be discharged away from the main dam into the canyon below.

As a further protection against any churning action of the water which may occur, large blocks of riprap should be laid against the lower toe wall of the dam to prevent the scouring of a large cavity in the bed of the canyon at that point. The lower toe wall should be provided with weep holes, so that hydrostatic pressure against the wall can be avoided. It is believed that the body of sand and gravel between the two toe walls of the dam, which is 234 feet in length and approximately 400 feet in width and which is rigidly sustained by two masonry retaining walls, will be a foundation of a very substantial and satisfactory character for the loose rock embankment composing the dam.

It is a frequent practice in sinking iron caissons for bridge piers to build concrete upon a retained sand foundation of this nature. When the foundations of the retaining walls are uncovered and examined, if the bed rock should prove unsuited to sustain the vertical pressure due to their weight, which will amount to a maximum of 12 tons per

square foot, then the walls will have to be broadened at their base to the proper width to reduce the pressure to the desired limit.

It is believed that a dam could be constructed at the Buttes on the plan outlined that would be a reliable and creditable engineering structure, but the expense would be great, as is shown in the estimate.

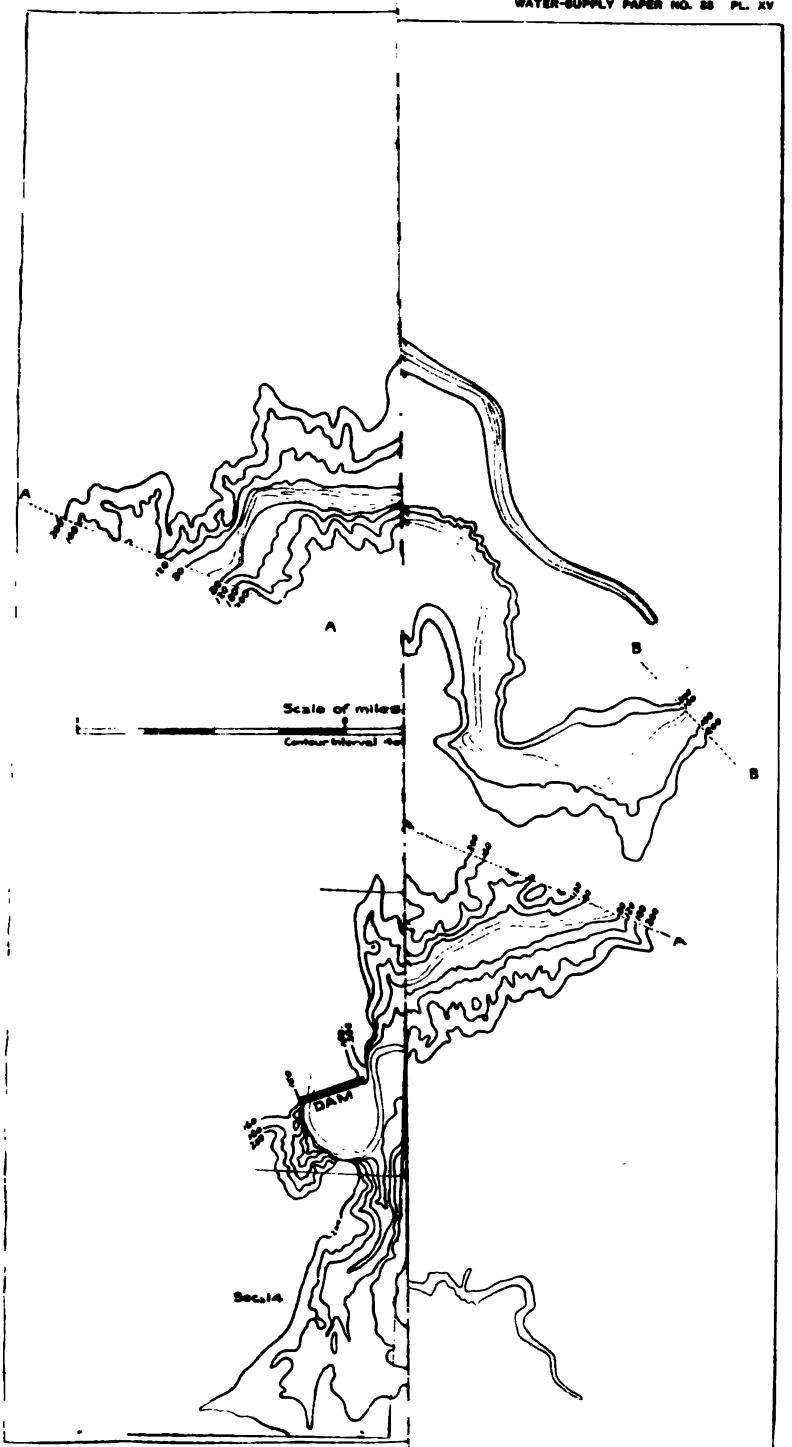
METHOD OF EXCAVATION FOR FOUNDATIONS.

The most serious difficulty in connection with the construction of a dam at the Buttes will be in the excavation for foundations. The plan suggested is the sinking of a series of open caissons. These will be put down as for bridge pier work. They would be weighted on top, and the excavation made probably below water by means of buckets on an endless chain or some similar method. As the excavation in the sand and gravel would progress, the caissons would sink on account of the superimposed weight, and new sections would then be fitted to the top as it went down. The borings with the diamond core drill did not indicate bowlders of large size, and it is believed that these caissons could be put down without serious trouble. The attempt would not be made to keep them pumped out until they reached bed rock, when pumping would be resorted to, the bed rock would be cleaned and examined, and after everything was clear they would be filled with concrete.

A row of these caissons, tangent to each other, would be put down at the upper face of the upper toe wall, and another at the lower face of the upper toe wall, each row being braced against the other. The bed rock where the upper toe wall would be put down is at a maximum depth of 71 feet, and is better than the average bed rock which intervenes between the two retaining walls. At the lower toe wall the bed rock is largely pearlite, and is at a maximum depth of 122.6 feet. The principal trouble in putting down these foundations will be in handling the volume of water to be encountered. Bed rock is nearer the surface at the upper toe than elsewhere. The wall would be naturally put down first here, and this would greatly relieve the volume of water to be handled at the lower toe wall. The two rows of caissons having been placed, the sand and gravel intervening would then be excavated. When the excavation is completed for the upper toe wall between the cylinders, the concrete to constitute the wall would then be placed in solid mass. A similar construction would be followed at the lower toe wall. With the two toe walls completed, the riprap would be placed between them and allowed to sink to the greatest depth possible into the sand.

BUILDING MATERIALS, SAND AND GRAVEL.

A drainage line enters the Gila River at a distance of about 2,000 feet above the dam site, which carries the discharge from an area lying south of the reservoir site. This drainage line for a distance of


A
A
B
B
Scale of miles
Contour interval 40
DAM
Sec. 14

3 or 4 miles varies in width from 100 to 400 feet and is filled to an unknown depth with a high-grade, coarse building sand, the voids constituting 35 per cent of the mass. This sand would have to be washed, and would then be of good quality for concrete. The cement for the dam must be shipped, probably, from California to Casa Grande, at a cost for railway transportation of $12.20 per 2,000-pound ton. The wagon haul from the railroad to the Buttes is 40 miles. The amount of cement used should, therefore, be reduced as much as possible. An examination was made for materials from which a natural hydraulic cement could be made, without successful results. Limestone exists 3 or 4 miles below the Buttes dam site, but no good clay was found. Fuel also would be an expensive element. Coal would have to come from New Mexico, if used, and wood from the neighborhood of the Indian reservation.

A test, as noted on page 16, was made to determine the possibility of making a silica cement with the Portland cement, which might be brought in, and finely ground pearlite. By mixing one portion of finely ground cement with an equal bulk of pearlite, so that no residue would remain on a 200-mesh sieve, and adding two parts of coarse sand, not ground, making a mixture of one part finely ground Portland cement and five parts sand and ground silica, a tensile strength of 80 pounds per square inch was obtained at the end of seven days and of 300 pounds at the end of twenty-eight days. When the same cement was mixed with sand on the ratio of 1 to 2, 33 per cent being left on the 200-mesh sieve, a tensile strength of 170 pounds per square inch was obtained at the end of seven days and of 385 pounds at the end of twenty-eight days. The same pure cement mixed on a ratio of 1 to 3 has a tensile strength of 140 and 240 pounds per square inch at the end of seven and twenty-eight days, respectively. The ground pearlite and finely ground cement mixed on the ratio of 1 to 7 has a tensile strength of 185 pounds per square inch at the end of twenty-eight days.

CAPACITY AND COST OF THE BUTTES RESERVOIR.

The basin of this reservoir site, shown on Pl. XV, embraces little agricultural land, and it is estimated that $10,000 will cover all the damages that would be incurred by appropriating it for reservoir purposes. Some copper prospects have been discovered in the reservoir site at a point known as the Dikes, but it was subsequent to the filing on all of this land under the United States laws for reservoir purposes. No further antagonistic interests can become vested here.

The capacity of the Buttes reservoir site is 174,040 acre-feet, and the estimated cost of constructing this dam is $2,643,327, or an average cost of $15.19 per acre-foot of capacity. The Buttes reservoir site has the advantage of being closer to the irrigable lands than any other of the reservoir sites considered on this river.

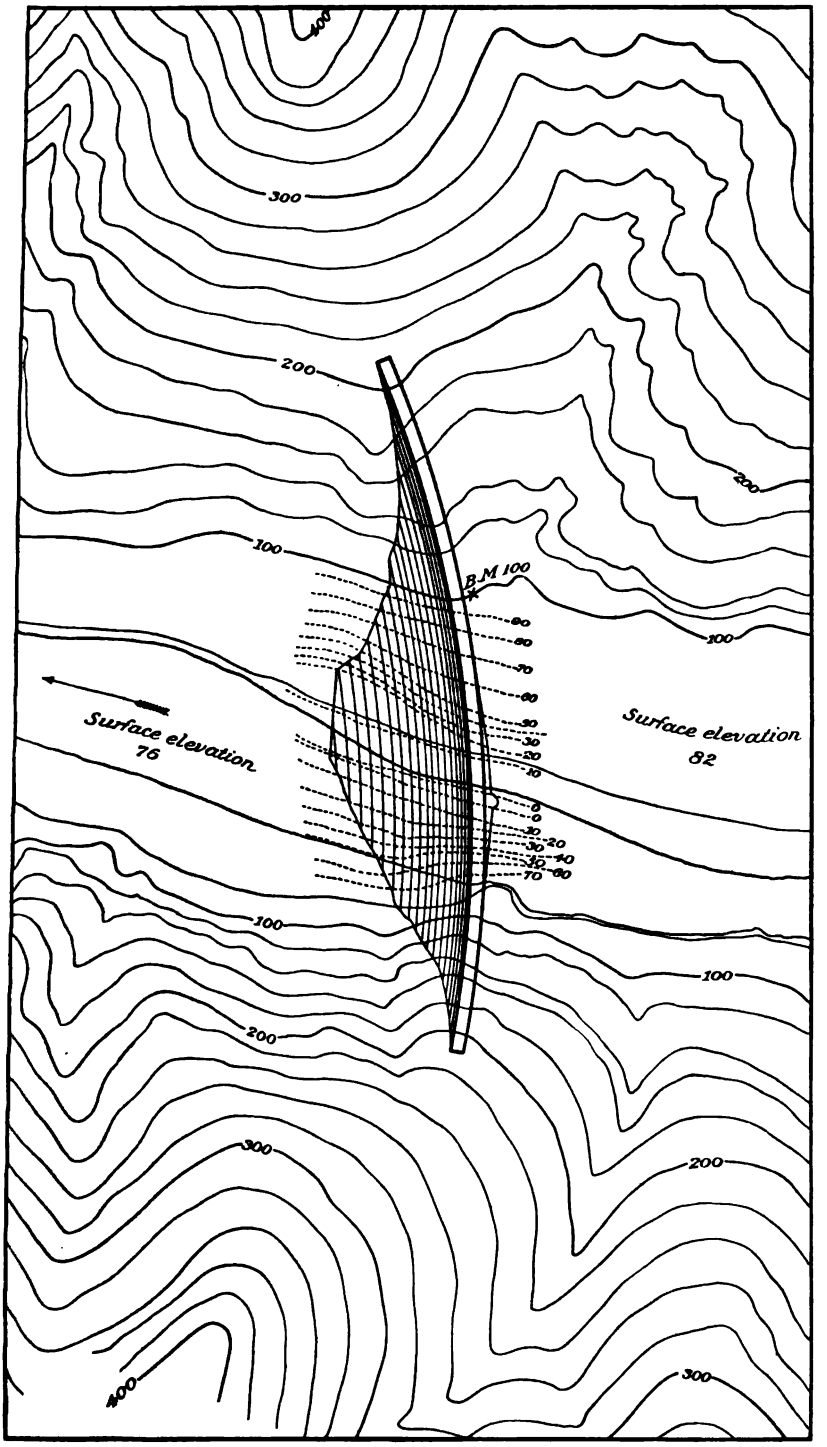
Area and capacity of the Buttes reservoir site.

Contour flow line.	Area.	Capacity, section.	Capacity, total.
	Acres.	*Acre-feet.*	*Acre-feet.*
10	20	100	100
20	71	450	550
30	229	1,500	2,050
40	397	3,130	5,180
50	533	4,650	9,830
60	741	6,370	16,200
70	928	8,345	24,545
80	1,105	10,165	34,710
90	1,329	12,170	46,880
100	1,566	14,475	61,355
110	1,769	16,675	78,030
120	2,029	18,990	97,020
130	2,367	21,980	119,000
140	2,746	25,565	144,565
150	3,149	29,475	174,040
160	3,602	33,755	207,795
170	4,118	38,600	246,395
180	4,609	43,635	290,030
190	5,133	48,710	338,740
200	5,651	53,920	392,660
		392,660	

Estimate for the Buttes dam.

Rock excavation for dam and riprap, 305,805 cubic yards, at $1	$305,805
Masonry in walls above ground, 137,032 cubic yards, at $6	822,192
Concrete tower, 37,328 cubic feet, at 50 cents	18,664
Tower house	750
8 inlets, at $500 each	4,000
4 balance valves, at $1,000 each	4,000
Footbridge, 120 feet, at $10 per foot	1,200
Masonry below water:	
Lower wall, 478,800 cubic feet, at 90 cents	430,920
Upper wall, 798,800 cubic feet, at 70 cents	559,160
Steel plates in face wall:	
1,152,000 pounds, at 7 cents	80,640
Low-water tunnel, 1,000 feet, at $15	15,000
Tower for flood gate	18,664
Tower house	750
Right of way	10,000
Upper outlet tunnel, lined, 320 feet, at $15	4,800
Bulkhead for same, 200 yards concrete, at $10	2,000
Woodcrib diversion dam at head of Florence canal, 500 feet, at $40 per linear foot	20,000
	2,298,545
Engineering and contingencies, 15 per cent	344,782
Total	2,643,327

Cost per acre-foot of water stored, $15.19.



CONTOUR MAP OF RIVERSIDE DAM SITE.

DIVERSION CANAL BELOW THE BUTTES DAM.

A topographic map was made on a scale of 100 feet to the inch, with 5-foot contours, showing possible locations of a diversion canal from the Buttes dam site to a point near the head of the Florence canal, which is practically at the head of the irrigable lands to be supplied from this reservoir. This topography was mapped by Mr. Bradford Wheeler, of Los Angeles, California. A grade line for the proposed conduit was computed. Flags were then set with a level upon the 10-foot contour nearest the grade from the dam through to the head of the irrigable lands. A transit stadia line was then run between these contour flags, transit points being set at intervals not to exceed 500 feet. This transit line was then plotted upon plane-table sheets, which were taken into the field, and the topography was filled in by means of the plane table. Instructions were to keep the accuracy of the map within the limit of the contour interval. The elevation of the contour flags was the vertical control for the work and the angular transit line was the horizontal control.

Upon this topographic map the canal location has been studied. The outlet tunnel, on the west bank of the reservoir, is placed at an elevation of 30 feet above the bed of the stream, the storage capacity lost below this elevation being immaterial. This would afford a bed-rock diversion and no loss by seepage. The capacity of the proposed canal is 500 cubic feet per second. The grade of the canal being lighter than that of the river permits of a gain in relative elevation and the possible development of power. The principal point gained by the construction of a canal as planned would be one of power.

A drop of 18.11 feet could be obtained at station 79+80, which, with 500 second-feet in the canal, would develop about 800 horsepower. If this horsepower could be sold at $50 per horsepower per annum, it would pay 5 per cent on a capital of $800,000. In a settlement such as would be built up upon the irrigation of 100,000 acres of land this power might be sold. When the time arrives that would make the power of sufficient value to justify the construction of the canal, it may then be built. Prior to that time the water from the outlet tunnels can be discharged into the bed of the Gila River and diverted at the present head of the Florence canal, where projecting ledges of rock are suitable for that purpose. The cost of the construction of this canal, therefore, should not be an element in estimating the cost of the Buttes dam. The water from either the Riverside or San Carlos reservoirs, which would be discharged directly into the Gila River, would necessarily be diverted for irrigation purposes at the head of the Florence canal, which is the point where water from the Buttes reservoir site could also equally well be diverted.

Cost of the Buttes canal.

15,510 lineal feet of lined canal, in rock, at $8.80 per lineal foot	$136,488
400 lineal feet of lined canal, in loose rock, at $6.73 per lineal foot	2,692
5,120 lineal feet of earthen canal, 57 cubic yards excavation, per lineal foot, at 30 cents per cubic yard, $1.71 per lineal foot	8,755
580 lineal feet of lined tunnel, at $10.65 per lineal foot	6,177
610 lineal feet of earthen canal, lined, at $7.94 per lineal foot	4,843
1,960 lineal feet of flume and trestle, at an average cost of $17 per lineal foot	33,320
24,180 lineal feet of conduit	192,275
Engineering and contingencies	28,840
Total	221,115

4.59 miles, or about $48,000 per mile.

EXPLORATION AT THE DIKES.

Four miles above the Buttes dam site, on the Gila River, a dike of volcanic rock, apparently of more recent geological origin than the remainder of the country, crosses the stream. After the depth to bed rock at the Buttes was determined to be disappointingly great, it was thought possible that the depths might be less at the Dikes. A test was therefore made to determine this. Pipe was driven to a depth of 96 feet and 3 inches in the center of the canyon without reaching bed rock. As the width of the canyon at this point is 459 feet between the rock croppings at the two sides of the canyon, and as the better portion of the Buttes reservoir site in the way of capacity lies between the Buttes and the Dikes, this depth to bed rock is considered as having condemned that location for the construction of a dam.

RIVERSIDE RESERVOIR.

The Riverside reservoir site is located on the Gila River, in Pinal County, Arizona, between the mouth of the San Pedro and a point one-half mile below the mouth of Mineral Creek and 12 miles above the Buttes (Pl. XVIII.) The dam site is in a canyon one-half mile below the mouth of Mineral Creek. A view of this canyon, looking downstream, is shown on Pl. XVII, *A*.

The water supply at this point will be practically the same as that at the Buttes. There are no streams or drainage lines of consequence entering the river between the Buttes dam site and the dam site of the Riverside reservoir. The discussion of the water supply in the previous pages of this report will apply equally to the Riverside reservoir site and the Buttes.

The bed of the canyon between the projecting ledges at the two abutments is 350 feet in width. A bench mark is located on the right bank, 20 feet above the bed of the stream. It is a bronze tablet, set in the rock, such as is used to designate elevations by the Geological Survey. It is considered 100 feet above the datum plane of the dam and reservoir surveys.

A. RIVERSIDE DAM SITE, LOOKING DOWNSTREAM.

B RIVERSIDE RESERVOIR SITE.

This elevation of 100 feet is equivalent to 1,763.30 feet above sea level. The rock at this location is a granite, well suited for building purposes. The topographic survey of the dam site was made by Gerard H. Matthes, assistant hydrographer, United States Geological Survey, in 1899, on a scale of 100 feet to the inch, and with a contour interval of 10 feet. A dam has been projected upon this map as a basis for an estimate for this report at the point where bed rock was determined by the diamond core drill. The height of the dam above the bed of the stream as estimated is 133 feet; the maximum depth to bed rock is 78 feet, or a total height of structure of 211 feet. Large ledges of rocks are available for construction purposes at an elevation above the dam on either side of the canyon.

The accompanying map (Pl. XVI) shows by means of contours the walls of the canyon and also the location of the dam described above. This has been prepared from the detailed map made by Mr. Matthes, the 20-foot contour lines only being given. The dotted lines in the center of the map indicate the depth to bed rock as shown by the drill holes. The point marked "B. M. 100" on the map is at an altitude of 1,763.3 feet above sea level. The surface elevation of the bed of the stream immediately above the proposed dam is 76.8 feet, and immediately below, 76.1 feet. Five borings to bed rock were made along the upper face of the dam and six along the lower side, the position of these being shown on Pl. XIV, *C*.

PROPOSED DAM AT RIVERSIDE.

The dam at this point should be an overflow weir, as the topography is not suited to the artificial construction of spillways on either side. The bed rock developed by the borings is a heavy granite, suited to withstand any pressure that may be put upon it by a dam. The quality of the building material, the topography, compelling an overflow weir, and the substantial character of the bed rock, determine a masonry structure as the best suited for this site. The section of dam proposed for San Carlos (Pl. XXII), described in detail under the discussion of that reservoir site, is the one selected as the basis of the estimate for the Riverside reservoir.

Eleven holes were put down with the diamond drills, their position being shown on Pl. XIV, *C*, at the point selected for the dam, and cores of bed rock were obtained. These borings are distributed across the canyon on two lines 150 feet apart, the holes in each row being between 50 and 60 feet distant from one another. The specific gravity of the rock is 2.51 and its weight per cubic foot is 157 pounds. Its strength to resist pressure was beyond the limit of the testing machine used, 2,535 pounds, which is equivalent to 184 tons per cubic foot. This guarantees it to be strong enough for the purpose required. The following table gives the log of the holes at this dam site. Two additional holes were put down 380 feet above the accepted

dam site, in order to determine whether bed rock was nearer the surface at this point. One hole went down to an elevation of 6 feet above the datum plane, or 76 feet in depth, and the other to an elevation of 11 feet, or a depth of 68 feet. Bed rock was not encountered at either one of these points, and as the canyon is wider here than below, it is evidently inferior to the site where the principal borings were made. Hence no alternative selection was attempted.

Log of holes at Riverside dam site.

Line.	Hole No.	Depth to bed rock.	Depth drilled in bed rock.	Elevation of bed rock.	Quality of rock.
		Feet.	*Feet.*	*Feet.*	
A	1	74.0	1.33	1,667.3	Hard driving.
A	2	75.5	5.00	1,664.7	Hard driving at 50 feet; bowlders.
A	3	27.00	4.00	1,713.1	
A	4	32.75	4.25	1,713.3	
A	5	16.00	.66	1,734.1	
B	1	48.00+	2.00	.....	Bed rock doubtful.
B	2	44.33+	.....	.....	No bed rock; bowlders
B	3	31.00+	.....	.....	Very hard driving; no bed rock.
B	4	73.50+	.....	.....	Do.
C	1	24.00	2.00	1,716.9	Gravel and sand.
C	2	49.00	3.00	1,690.4	Bowlder.
C	3	69.00	3.25	1,670.7	Bowlders.
C	4	64.33	5.16	1,673.7	Do.
C	5	65.00+	.....	.....	Bed rock doubtful; possible edge of cliff.
C	6	27.00	2.25	1,729.0	
C	7	63.00	10.75	1,682.9	

NOTE.—Add 1,663.3 to elevation on contour maps for sea datum.

METHOD OF CONSTRUCTION.

As the quarries from which the material for the dam may be obtained can be properly located approximately on the axis of the structure, cableways could probably be best used for putting the rock in place. The method of excavating to bed rock at this point might be that recommended at the Buttes, although it is possible that further investigation may determine that simpler methods of excavation will be sufficient. Sand suitable for concrete work may be found in large beds throughout the canyon. Along the wagon road from the Riverside stage station to Globe large ledges of quartzite occur. Masses of this material have rolled down the drainage line practically to Gila River and at distances not exceeding 4 miles from the dam site. This quartzite when ground is suited for mixing with finely ground Portland cement for making silica cement. This would cheapen the cost of cement for the construction of a dam. The railroad station to which material for the dam will be shipped is Casa Grande. The freight on cement from Los Angeles to Casa Grande is $12.20 per ton, or $2.32 per barrel. There would then be a wagon haul of 50 miles over fairly good roads from Casa Grande to the dam site. This haul would cost approximately $1.35 per barrel. With cement at $2.85 per barrel at Los Angeles, the cost delivered at the dam would be $6.52. A dam 133 feet in height across the bed of the stream, as described above, would require 186,147 cubic yards of masonry.

F RIVERSIDE RESERVOIR SITE

CAPACITY AND COST OF RIVERSIDE RESERVOIR.

The Riverside reservoir site was surveyed by Gerard H. Matthes, assistant hydrographer, U. S. Geological Survey, and mapped on a scale of 1,000 feet to 1 inch, with contour intervals of 10 and 20 feet, reaching an elevation of 214 feet above the bed of the stream at the dam site, which is the 290-foot contour of the reservoir survey. With a height of dam of 133 feet, or to the 210-foot contour, the length of the reservoir would be approximately 14 miles, and to the 230-foot contour, or a height of dam of 153 feet, approximately 15½ miles. The width varies at different points from a half mile to a mile. The principal breadth is from 3 to 6 miles above the Riverside stage station. A dam 130 feet in height to the spillway at the Buttes would store 206,000 acre-feet. A dam 133 feet in height at Riverside will impound 221,134 acre-feet, which is almost double the capacity of the Buttes reservoir site. A dam 130 feet high to the spillway at San Carlos will impound 241,396 acre-feet, which is the best of the three for this size of dam. With a dam 150 feet high to the spillway at the Buttes, which is the height upon which the estimate is based, 174,040 acre-feet would be impounded. A dam at Riverside of a height of 153 feet would impound 344,398 acre-feet, which is double the capacity of the Buttes, and a similar dam of 150 feet at San Carlos would impound 377,176 acre-feet.

The Riverside reservoir site is situated in a mineral district. Copper is found in large quantities in this neighborhood, and in August, 1899, there were 29 copper claims that would be wholly or in part flooded in case a dam 150 feet in height should be built. These claims are not being worked commercially, but are at present "prospects." With a railroad built to this mineral field, it is quite likely that a number of these claims could be worked at a profit. The Ray mine, which is being actively worked, is a short distance above the reservoir site on Mineral Creek. The owners are making an effort for the construction of a railroad to the mines. It would be undesirable to interfere with mining operations, which might develop valuable properties if interference could be avoided. The condemnation of right of way would be one of the greatest expenses in connection with the utilization of this reservoir site for storage purposes. It is probable that it would cost $200,000 without court expenses, which would easily amount to $50,000 more. There are under cultivation at present in the reservoir site 332 acres of land. These fields are irrigated by a small ditch. There is held in private ownership in the reservoir site 1,800 acres. This land would probably cost $20 an acre to condemn, or a total of $36,000.

Capacity of proposed Riverside reservoir.

Contour flow line.	Height of dam above bed of stream.	Area.	Capacity of section.	Total capacity.
	Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*
80	8			
90	18	28	196	196
110	38	197	2,252	2,447
130	58	600	7,972	10,419
150	78	1,811	18,005	28,424
170	98	2,316	36,270	64,694
190	118	3,967	62,832	127,526
210	138	5,395	93,607	221,134
230	158	6,924	123,174	344,308
			344,308	

NOTE.—Elevations based on datum of dam survey; 100 feet = 1,763.30 sea datum.

Estimate of cost of Riverside dam.

Masonry (half large rock and half concrete), 186,147 cubic yards, at $4.10 per barrel for sand cement, or $3.74 per cubic yard for cement (see Duryee's report), at $5.50 per cubic yard		$1,023,809
Excavating for foundations, 90,740 cubic yards		450,000
Towers and houses		12,000
Valves		3,500
Footbridges		6,000
Wooden crib diversion dam at head of irrigation canal		20,000
Total		1,515,309
Contingencies, 10 per cent	$151,531	
Engineering, 5 per cent	75,765	
		227,296
Total construction cost		1,742,605
Damage and condemnation proceedings		250,000
		1,992,605

Total number of acre-feet stored is 221,134, at a rate per acre, stored, of $9.01.

SAN CARLOS RESERVOIR.

San Carlos reservoir site is located on Gila River, on the White Mountain Indian Reservation, at the San Carlos Agency, in Gila County, Arizona, at a point where San Carlos River joins the Gila. The Gila Valley, Globe and Northern Railway, which leaves the main line of the Southern Pacific at Bowie Station and runs to the town of Globe, passes across this reservoir site. The Gila River at this point traverses some spurs of the Pinal range of mountains, and for a distance of 31.5 miles below the dam site the river flows in a narrow box canyon. This canyon extends to Dudleyville, which point is the upper end of the Riverside reservoir site. The river then passes through the Riverside reservoir site for a distance of 15.5 miles, after which it again enters a canyon, which is the upper end of the Buttes reservoir site. This latter canyon extends to the Dikes, which is 4 miles above the Buttes dam site. The total length of river from San Carlos dam site to the Buttes dam site is approximately 60 miles; about 40 miles of this distance being box canyon, and the remaining portion being valley land, of from 1 to 3 miles in width.

SAN CARLOS DAM SITE, LOOKING UPSTREAM.

Six miles below the San Carlos Agency, where the river enters the box canyon and approximately a half mile below the beginning of the box, is a point where the canyon is about 90 feet wide at the water line and where its walls rise very abruptly directly from the river. Pl. XIX shows a view of the dam site looking upstream. The dam will be located at the point where the wall of the canyon is shown to be most abrupt. Pl. XX shows the dam site as surveyed, with a contour interval of 10 feet. The dotted contours show bed rock as indicated by the borings. At a point approximately 100 feet above the upper face of the location selected for the dam there has apparently been a fault in the rock of the canyon. If the dam were located above this fault, there would be the possibility of a leak occurring between the strata and of water passing through the fault to the channel of the river below the dam. If the dam is built where located, this will be obviated.

The narrowest portion of the canyon is approximately 400 feet in length, and immediately below this narrow point it widens out to 300 feet at the low-water line. This admits of a spillway provision as shown in the plan of the dam (Pl. XX) and described in the account of the dam proper. The dam is located at the point shown in the plan, therefore, in order to obtain better spillway advantage, to secure better foundations and abutments, and to avoid the leakage through the strata above the line of fault.

The question of water supply available at San Carlos has been fully treated in preceding pages of this report in the discussion of supply available at the Buttes and at San Carlos, to which reference is made. The supply is ample to fill the reservoir with a dam 130 feet in height to the spillway, as planned. The table on the following page shows the amounts probably available at the San Carlos reservoir for each month. In this table the inflow, consumption, and evaporation are treated in the same manner as in the table on page 33, under the discussion of water supply for the Buttes reservoir site. It has been determined that the difference between the amount of water available for storage at San Carlos and the Buttes was 10 per cent, and this deduction of 10 per cent has been made in all estimates for the supply at San Carlos as measured at the Buttes.

The water which is released from the San Carlos reservoir site will pass through approximately 40 miles of box canyon on its way to the irrigable lands where it is to be used. Comparative measurements made at the Buttes and San Carlos during the dry season of the year, when less than 10 second-feet of water was flowing in the river at San Carlos, indicate practically an equal amount of water at San Carlos and the Buttes. There undoubtedly is a substantial loss from evaporation between these points, but this loss is compensated for by the seepage water which returns from the Riverside Valley and from the valley above the Buttes dam site. In the case of the Riverside Valley a few second-feet of water is used for irrigation, and the return

from this irrigation augments the stream. In both valleys, however, the high stages of the river undoubtedly charge the sand bars and gravel beds with water, and these are gradually drained off during the lower stages of the stream and, as has been stated, give practically an equal amount of water at San Carlos and the Buttes.

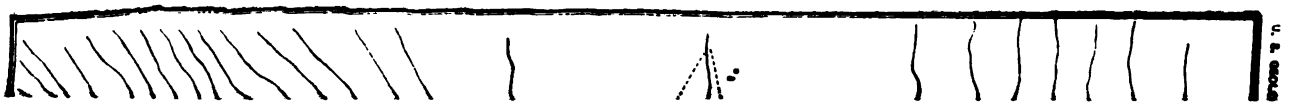
The San Pedro and the other drainage lines entering the Gila above the Buttes and below San Carlos will contribute their portion to this stream, unregulated by a reservoir built at San Carlos. This water can be used for irrigation around Florence if diverted below. If this volume of water and the return water from seepage is added to the water which is discharged for irrigation from the San Carlos reservoir site, it is probable that there will be available for irrigation at the point of diversion as much water as would be discharged from the San Carlos reservoir site.

If the Gila River from the San Carlos dam site to the Buttes dam site is 60 miles in length and 200 feet in width, it will expose to evaporation a water area of 1,454 acres. The depth of evaporation per annum has been previously determined as 91 inches, or 7.58 feet. With an area of 1,454 acres and a depth of evaporation of 7.58 feet there will be lost from this body of water 11,021 acre-feet. This would be 4.6 per cent of the total capacity of the San Carlos reservoir site, and, in order to make an allowance for all possible loss, 5 per cent of the water discharged from San Carlos is assumed as being lost for irrigation below the Buttes. The Riverside Valley and the valley above the Buttes are both largely public domain, and there is no reason why the water from the San Carlos reservoir should not be used for irrigation purposes at these points, as well as below Florence. This being the case, there will be but a slight disadvantage in storing water at San Carlos. A loss of 5 per cent in transmission is accepted in the following table and added to the amount to be liberated from the reservoir:

Estimated amount of water available from San Carlos reservoir.

[Capacity of reservoir is 241,396 acre-feet; 100,000 feet assumed to be in reservoir November 1.]

Month.	Inflow.	Per cent of capacity of reservoir used in irrigation.	Outflow for irrigation.	Loss of 5 per cent in transmission to point of irrigation.	Total amount turned out of reservoir for irrigation.	Depth of evaporation.	Area exposed to evaporation.	Loss by evaporation from reservoir.	Total loss from irrigation and evaporation.	Balance in reservoir at end of month.
	Acre-ft.	*Per ct.*	*Acre-ft*	*Acre-ft*	*Acre-ft*	*Feet.*	*Acres.*	*Acre-ft*	*Acre-ft*	*Acre-ft.*
November	32,842	2	4,828	241	5,069	0.42	3,650	1,533	6,602	126,240
December	27,117	2	4,828	241	5,069	.333	4,100	1,553	6,422	146,935
January	36,745	2	4,828	241	5,069	.25	4,690	1,173	6,242	177,438
February	24,008	5	12,071	604	12,675	.333	5,130	1,710	14,385	187,061
March	21,405	7	16,898	845	17,743	.50	5,225	2,612	20,355	188,109
April	18,433	9	21,725	1,086	22,811	.58	5,760	3,341	26,152	180,390
May	7,227	14	33,795	1,690	35,485	.83	4,680	3,884	39,369	148,248
June	3,665	14	33,795	1,690	35,485	.92	3,110	2,861	38,346	113,567
July	59,170	13	31,381	1,569	32,950	1.00	4,060	4,060	37,010	135,727
August	69,522	13	31,381	1,569	32,950	1.08	4,370	4,720	37,670	167,579
September	47,256	11	26,554	1,328	27,882	.83	4,950	4,109	31,991	182,838
October	74,800	8	19,312	966	20,278	.50	5,714	2,857	23,135	234,501
Total	422,184	100	241,396	12,070	253,466	7.58	.....	34,211	287,477	.....



There is still an amount available for irrigation below the Buttes, on the basis of the above table, for a mean year, equal each year to the full capacity of the San Carlos reservoir, of 241,396 acre-feet, with a minimum reserve in reservoir of 113,567 acre-feet, and 234,507 acre-feet on November 1, for use during the following season. The discharge of the Gila River during 1899 was less than during any other year of which we have record. The following table demonstrates that 241,396 acre-feet of water could have been delivered below the Buttes from San Carlos from November 1, 1898, to October 31, 1899, with a minimum reserve in the reservoir during that period of 12,269 acre-feet and 96,088 acre-feet in reservoir with which to begin the season of 1899–1900:

Estimated amount of water available from San Carlos reservoir during 1898–99.

[Capacity of reservoir, 241,396 acre-feet; 100,000 acre-feet assumed to be in reservoir November 1, 1898.]

Month.	Inflow.	Per cent of capacity of reservoir used in irrigation.	Outflow for irrigation.	Loss of 5 per cent in transmission to point of irrigation.	Total amount turned out of reservoir for irrigation.	Depth of evaporation.	Average area exposed to evaporation.	Loss by evaporation from reservoir.	Total loss from irrigation and evaporation.	Balance in reservoir at end of month.
1898.	*Acre-feet.*	*Per cent.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Feet.*	*Acres.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
November	5,409	2	4,828	241	5,069	0.42	3,460	1,453	6,522	98,887
December	16,878	2	4,828	241	5,069	.333	3,560	1,185	6,254	109,511
1899.										
January	17,555	2	4,828	241	5,069	.25	3,710	928	5,997	121,069
February	11,946	5	12,071	604	12,675	.333	3,700	1,232	13,907	119,108
March	7,194	7	16,898	845	17,743	.50	3,600	1,800	19,543	106,759
April	3,320	9	21,725	1,086	22,811	.58	3,310	1,920	24,731	85,348
May	996	14	33,795	1,690	35,485	.83	2,650	2,200	37,685	48,659
June	276	14	33,795	1,690	35,485	.92	1,610	1,181	36,666	12,269
July	65,754	13	31,381	1,569	32,950	1.00	1,570	1,570	34,520	43,503
August	a24,884	13	31,381	1,569	32,950	1.08	2,050	2,214	35,164	33,223
September	39,260	11	26,554	1,328	27,882	.83	2,000	1,660	29,542	42,941
October	b74,800	8	19,312	966	20,278	.50	2,750	1,373	21,653	96,088
Totals	268,272	100	241,396	12,070	253,466	7.58	-------	18,718	272,184	----------

a Measured discharge of Gila Basin at San Carlos.
b Estimated mean discharge, in acre-feet, of Gila Basin above San Carlos for month of October, 1899.

PROPOSED DAM AT SAN CARLOS.

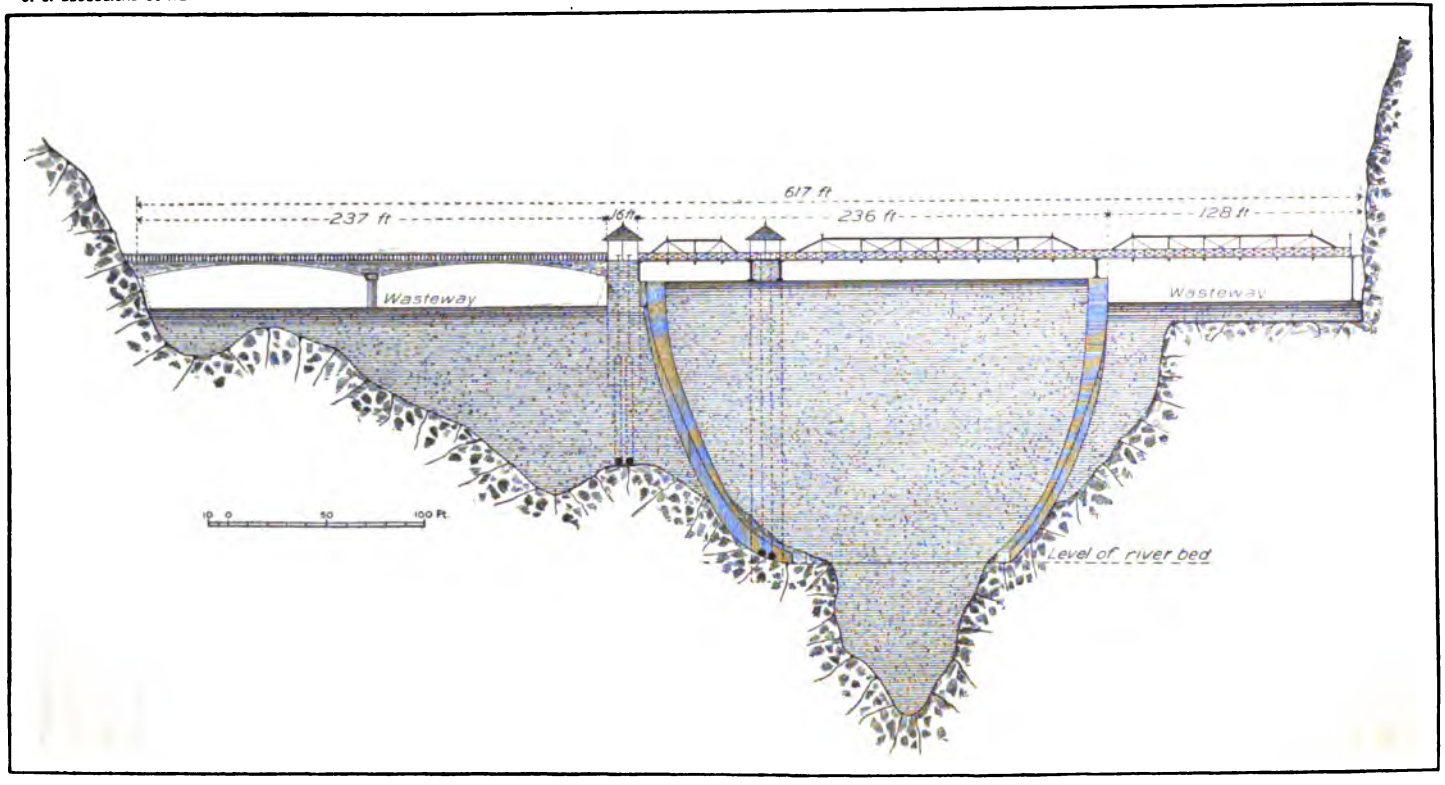
In determining the height of dam to be constructed at the San Carlos dam site two elements are to be considered. First, the amount of water available; second, the amount of expenditure which can be economically made. From a study of the water supply, shown on page 29, a dam 130 feet in height, storing 241,396 acre-feet, is justified. The year of lowest run-off of which we have a record is 1899. The discharge of the river for this year at San Carlos was measured until the 1st of October, and a monthly discharge for October, November, and December, as determined, has been added to complete the year.

This shows a surplus for the year 1899 above the capacity of the reservoir of 76,879 acre-feet. The mean surplus above the capacity of the reservoir at San Carlos is estimated at 180,788 acre-feet. The maximum height of the central portion of the dam above the bed of the stream is taken at 142 feet, and the maximum depth to bed rock below the surface of the stream at 74 feet. This would give a total maximum height of the central portion of the dam from bed rock at 216 feet. An increase of this height is considered unnecessary and as adding too much to the expense of the structure. The table on page 69 is believed to justify a dam of this size.

The San Carlos reservoir site was the last that was discovered upon the Gila River, and consequently the last point at which investigation for bed rock was made. After the completion of the borings at Queen Creek, the Buttes, and Riverside, the drilling outfit, in charge of Mr. Patrick Tierney, was sent by wagon from Riverside to San Carlos. This arrived at San Carlos in the latter part of June, 1899, and work was immediately begun at the dam site. The first flood on the Gila River in the summer of 1899 occurred on July 16 and was about 10,000 cubic feet per second in volume. This knocked over the drilling apparatus. It was restored to position, and frequent other interrupting floods occurred at intervals of two or three days during the remaining portion of July. The funds available for carrying on the work having become nearly exhausted, and the river continuing its flood discharges, it was not considered practicable to continue the investigation for bed rock during the present season.

Two holes were put down approximately on the lower toe of the dam. No. 1 was 33 feet to the right of bench mark No. 4, which is located on the left abutment, and No. 2 was 66 feet from the left abutment and approximately 30 feet from the right abutment. The depth to bed rock at hole No. 1 was 23 feet. The bed rock encountered is a very fine-grained and flinty limestone. It was so hard that only 2 feet 9 inches a day could be drilled into it with the diamond drills, which is about one-fourth the rate of progress in ordinary granite. The depth drilled into bed rock at this point was 12.5 feet.

Hole No. 2 determined the depth to bed rock to be 74 feet. Gravel was encountered at 72 feet. The rock at this hole is a blue limestone and is more easily drilled than the rock in hole No. 1. The total depth to the bottom of this hole was 81.82 feet, the depth drilled into bed rock being 7.82 feet. A third hole was put down in the center of the bed of the canyon 60 feet from the left abutment and 100 feet above line No. 1. A 2-inch pipe was driven to a depth of 56 feet and 2 inches, when it was found to be bent 2 feet from the bottom. The pipe was then pulled up and 2½-inch pipe driven to a depth of 51 feet in the same hole. No further progress could be made on account of the high water, and this hole was abandoned and all work stopped on July 31, 1899.



ELEVATION OF SAN CARLOS DAM AND WASTEWAYS.

The information concerning bed rock is meager, but it is considered fair to estimate the maximum depth of bed rock at 74 feet. The bed-rock itself is a very close-grained hard limestone and all that could be desired for foundation purposes. The location of the borings at San Carlos dam site is shown on Pl. XX.

MATERIAL FOR DAM.

Pl. XXV, *B*, shows a view of the left abutment of the dam. The strata dip downstream. It would be better if the dip were upstream, as there would be less danger of leakage beneath the foundation of the dam. The limestone, however, is exceedingly dense, not easily eroded, and, as will be seen on the right-hand side of the illustration, where a slide has occurred, the rock a few feet beneath the surface is relatively free from seams. The abutment on the right is of much the same nature as the abutment on the left.

The rock for the construction of the dam will be obtained near the top of the two abutments. It will be excavated in such manner as to form a channel for the flood waters to discharge over the two weirs, which are located at the two ends of the dam. Sufficient rock will be taken from these two channels, as shown by the plan, Pl. XX, to build the entire structure, and this will be enough to furnish flood channels for the maximum flood at this point, which is estimated to be within 10 per cent of the maximum flood at the Buttes. These quarries will be located at the end of the dam and practically on its axis, and in such position that material can readily be handled by means of cable for construction purposes. The haul of the material will be on a down grade, and the average distance will not exceed 200 feet. This is considered an ideal location for the economic use of cables. The quarry rock has a specific gravity of 2.7, or a weight of 168 pounds per cubic foot.

On the left abutment it is an exceedingly fine-grained pink limestone, much resembling flint, but showing, by analysis, percentages as follows: 55.92 carbonate of lime, 31 carbonate of magnesia, 3.70 silica, 6 alumina and ferric oxide, and 1 moisture. The gray limestone from the right abutment contains 96.65 carbonate of lime, 1.40 silica, 1.30 alumina and ferric oxide, 0.65 moisture. From an engineering standpoint it has the appearance of being a first-class building rock.

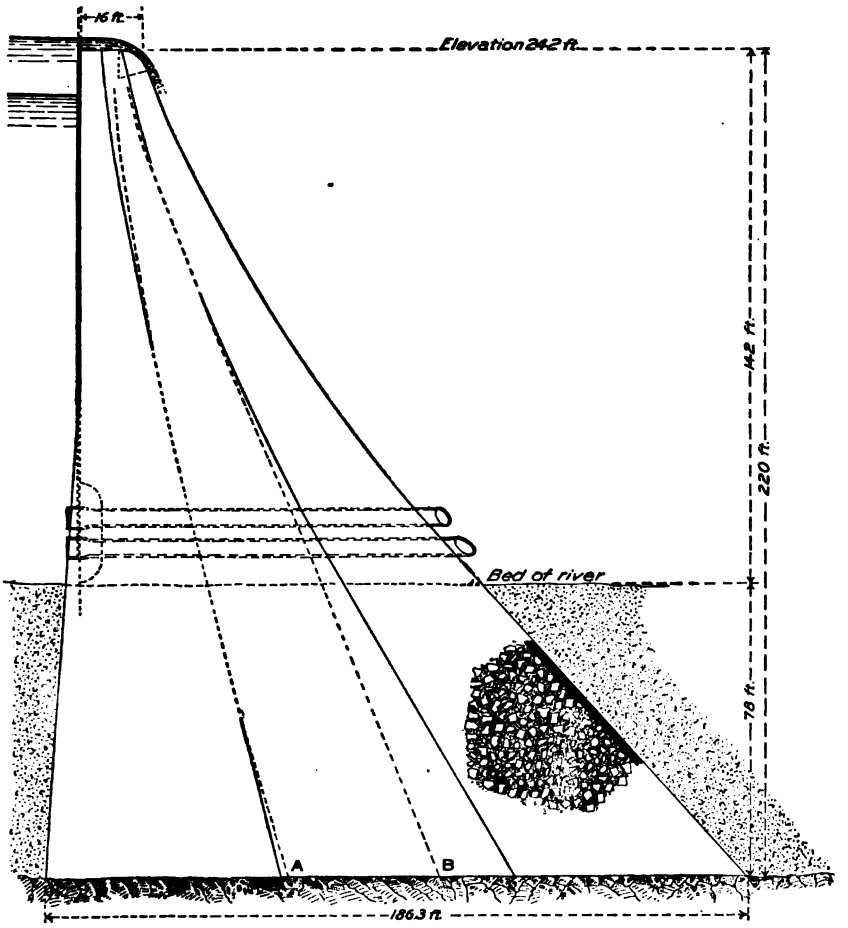
The sand required for the construction of the dam could be obtained in the canyon within a few hundred feet of the dam site. It is a good building sand, but would have to be washed before its use with cement. Gravel in varying sizes is found in connection with the sand and could be separated from it by screening. The quartzite that would be used at San Carlos is found in large ledges within 1,000 feet of the dam site. Mr. Duryee's report on cement is given on page 82.

DETAILS OF DAM.

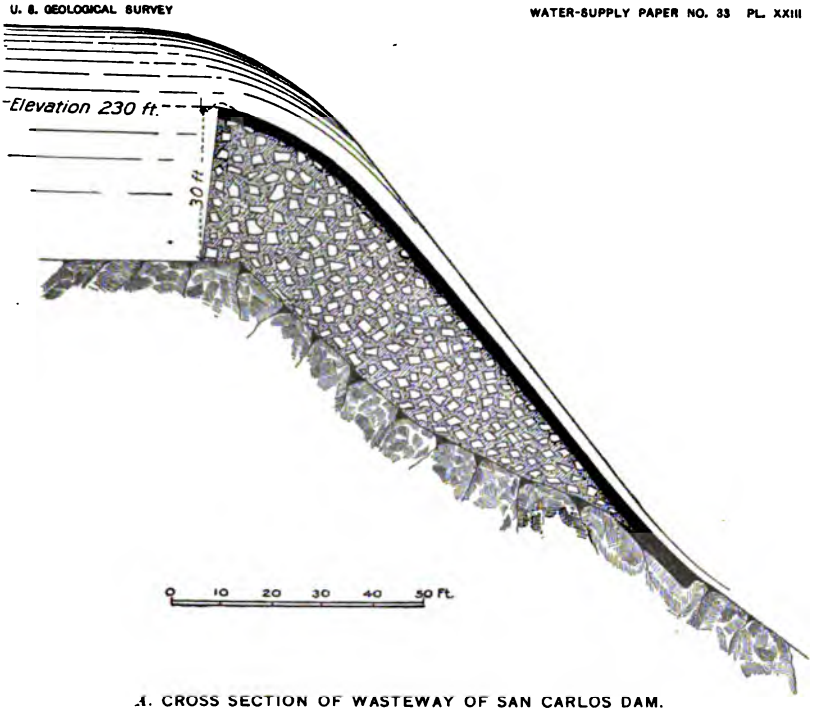
The dam selected for this site is shown in plan on Pl. XX, in section on Pl. XXII. The details are shown on Pls. XXI–XXVI. It is proposed to construct it of large irregular blocks of stone, bedded in concrete. The maximum height of this structure from deepest bed rock to the top of the central portion of the dam is 216 feet, and the maximum length is 617 feet. The total number of cubic yards contained in the dam, weir, and towers is 94,730. In order to avoid the erosion and shock which would result from a large flood passing over the central portion of the dam and falling 142 feet on its base, the middle part of the dam, for a length of 236 feet, has been planned to an elevation of 12.5 feet above the elevation of the wasteways on the sides. The section of the central portion of the dam (Pl. XXII) shows the line of pressure at B with 10 feet of water in depth passing over the crest, and also at A the line of pressure with an empty reservoir. Both these lines, for every portion of the dam, lie within the middle third, resulting in a safe gravity structure. The maximum pressure on the upper toe is 12 tons per square foot and on the lower toe 12½ tons per square foot. The weight of the masonry is assumed to be 150 pounds per cubic foot.

In addition to its strength as a gravity dam it is given an arched form. Expansion and contraction in a curved dam are more easily adjusted than in a straight dam. The spillway on the right bank (Pl. XXIII, *A*) would be 237 feet in length, and on the left abutment 128 feet in length. With 3 feet of water passing over the central portion of the dam and a corresponding depth of 15.5 feet discharged through the spillways over the two end weirs, the total discharge past the structure, exclusive of discharge through outlets, as estimated by T. C. Clarke's formula, is 83,620 cubic feet per second. This is considered as the maximum flood discharge of the Gila River at this point. It is fair to assume that the reservoir will not be wholly full at the time such a maximum flood would occur, and that the capacity of the reservoir will tend to relieve this flood discharge.

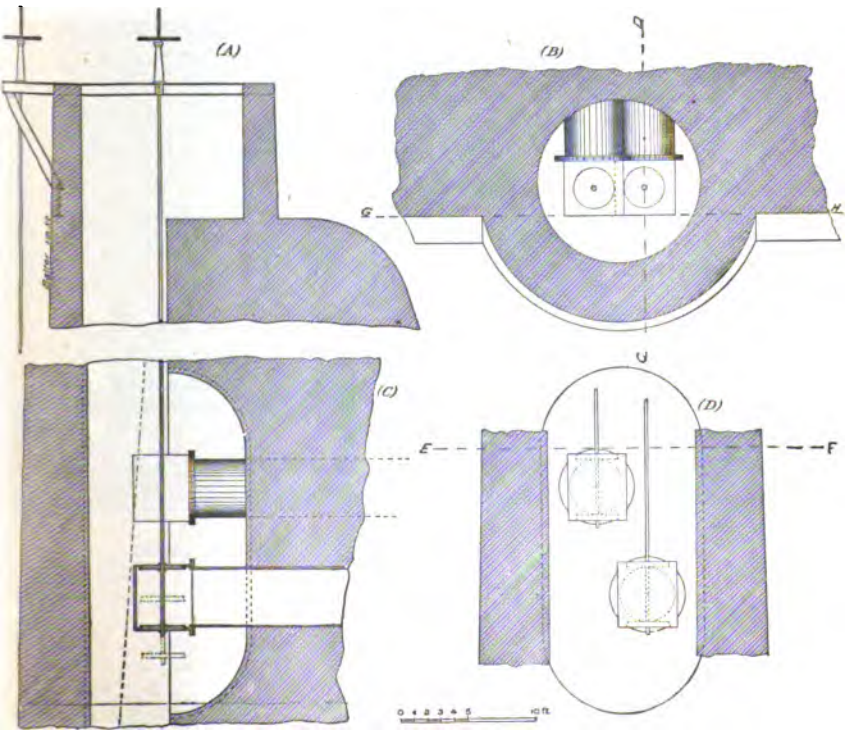
Two training walls have been planned from the ends of the central portion of the dam to protect its toe from the erosion of water passing over the spillways. This water will be discharged into the canyon below the lower toe of the dam in such manner as to project the overflow down the canyon away from the dam. The section of the wasteway weirs proposed for the two spillways is shown in Pl. XXIII, *A*. These weirs are to be built upon the sloping ledge rocks, and will have a slope on their lower face of 3 feet horizontally and 2 feet vertically. They will be of an exceedingly substantial nature, the surface being protected by from 2 to 3 feet of extra strong concrete. The water in passing over them will never leave the face, and consequently there will be no pounding action.



MAXIMUM CROSS SECTION OF THE SAN CARLOS DAM, WITH TOWERS REMOVED.

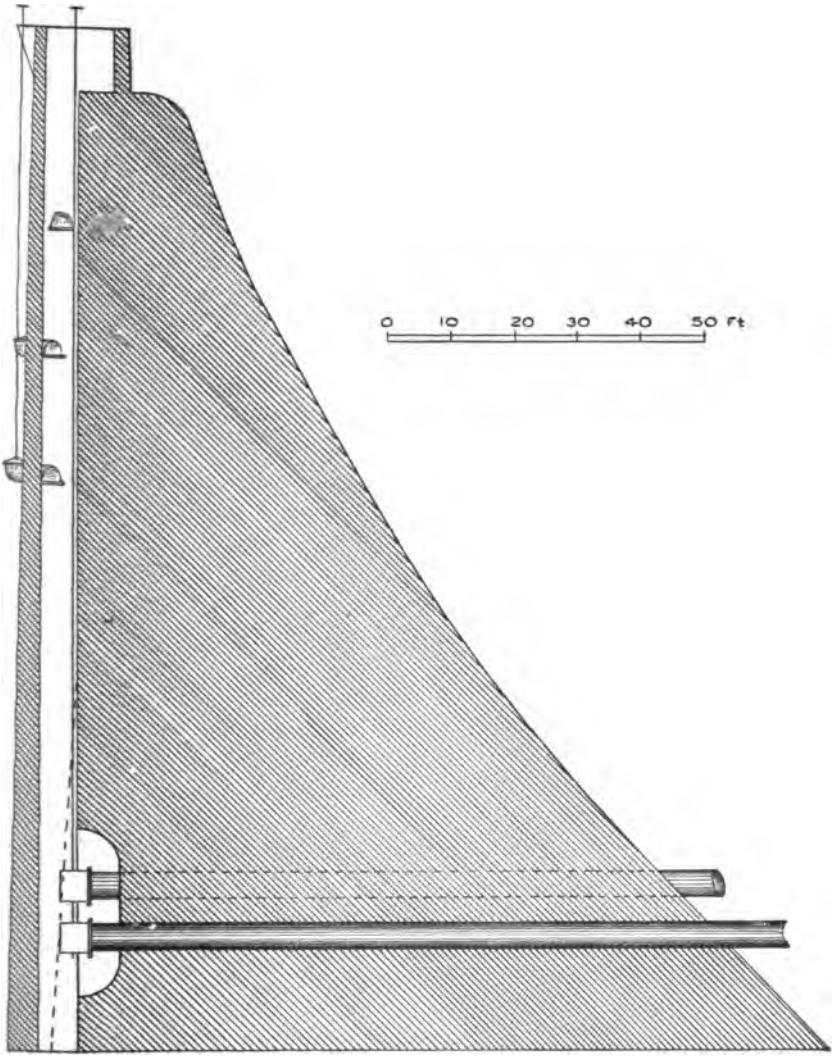


A. CROSS SECTION OF WASTEWAY OF SAN CARLOS DAM.



B. DETAILS OF TOWERS FOR SAN CARLOS DAM.

In the above figure sections are given of the outlet tower. At *B* is a horizontal section on the line *E F* of *D*; at *C* is the vertical section on the line *C D* of *B*, and at *D* is a vertical section on the line *G H* of *B*.



CROSS SECTION OF SAN CARLOS DAM THROUGH TOWER.

The outlet from the dam will be through two towers located near the right abutment. These towers will be semicircular, a portion of the opening being recessed into the dam, as shown by the details (Pl. XXIII, *B*). A series of intakes will be placed in this tower at varying elevations, the valve (Pl. XXVI, *A*) consisting of a plain cap or cover, as shown in the detail, which will be lifted by an ordinary wheel and screw. The intakes will be pipes 3 feet in diameter, and there will be six in each tower (Pl. XXVI, *B*). As the water should be drawn from near the surface of the reservoir at all times there will be very slight pressure to be overcome in lifting these valves, and this may be overcome by closing the balanced valves inside the tower, allowing the latter to fill with water through small by-pass valves, after which the pressure on the outer intake valves will be relieved. In case any one of the valves should become stuck, the water could be drawn into the tower from other valves, and when the general water plane fell below the elevation of the injured valve it could then be repaired. A second set of valves is to be located near the base of the tower. These valves will permit the water to discharge through two cast-iron pipes which will pass through the dam and which are to be 4 feet each in diameter. It will be possible to discharge water through four of these pipes, two being located in each tower, as shown in the elevation of the dam. The discharge through these pipes will vary with the depth of water in the tower.

As the valves for the discharge pipes may have to be operated under a considerable head of pressure, a balance valve has been decided upon as preferable. This valve is shown on Pl. XXIII, *B*. The action of this balance valve is in the nature of a double piston head, which is driven by a screw gear from above. One of these valves, or piston heads, is seated on each side of the valve box. They are equal in area, consequently the downward pressure on the upper valve is balanced by the upward pressure on the lower valve. When the valve is wide open one of these piston heads will be $2\frac{1}{4}$ feet below its seat, and the upper piston head will be in the center of the boxing. The water will therefore enter through both openings and discharge through the main pipe.

The towers were considered necessary in order to prevent the deposit of silt around the valves, or their clogging with drift. In case the inner valves become out of order the outer valves can be closed and the inner valves then repaired. Two towers have been designed, so that one complete set of valves can get out of order and the second set be used during the repair of the first. A bridge from each abutment to the towers has been planned, so that the dam may be crossed and all points on the top of the dam visited, even during maximum floods. Alternate designs for this crossing are shown on the elevation of dam and wasteways, one for an iron bridge and the other for a combination iron and concrete span.

The safety of this structure, considering the remarkably hard bed rock on which it is to rest, the fine character of the building stone that may be used, the heavy gravity section of the dam and the weirs that have been planned, the solidity of the abutments and the narrowness of the canyon, would be beyond question.

At a point 180 feet above the upper face of the dam, marked "B. M. No. 1" on the plan (Pl. XX), the canyon is but 88 feet in width between the abutment walls. This is apparently an ideal place to put down sheet piling to bed rock to intercept the underflow. The surface flow of the stream would then be diverted in a flume to a point below the dam. It is believed that the sand and gravel of the river bed could be solidified by injecting cement grouting through pipes into the voids of the sand between the sheet piling and the foundation excavation. This could be injected at various points and elevations and the mass sufficiently solidified to admit of the excavation to bed rock at the site of the dam.

CAPACITY AND COST.

The capacity of the San Carlos reservoir with the height of dam proposed is the greatest of any of the reservoir sites that were found on the Gila River by this survey. The elevation of the bed of the canyon at the dam site is assumed by the surveys as 100 feet and is equivalent to a sea elevation of 2,307 feet, as determined from the San Carlos railroad station. A United States Geological Survey brass bench-mark tablet has been placed at the dam site. The capacity of the San Carlos reservoir site is shown in the following table:

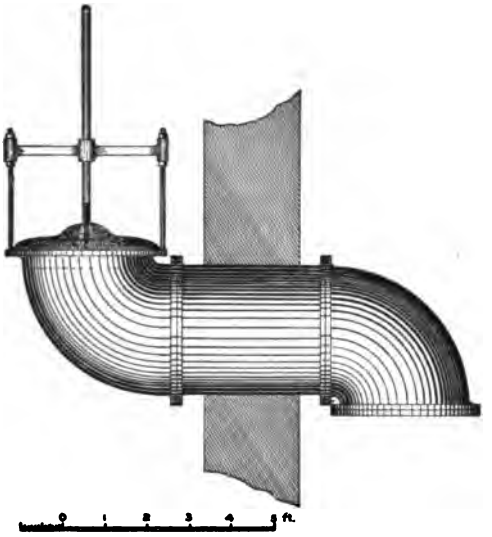
Capacity of San Carlos reservoir site.

Contour.	Area.	Contents between contours.	Total contents.	Mean depth.	Per cent of maximum depth.
	Acres.	*Acre-feet.*	*Acre-feet.*	*Feet.*	
100	0				
110	17.2	86.0	86.0	5.0	50.0
120	40.8	290.0	376.0	9.2	46.0
130	83.8	623.0	999.0	12.0	40.0
140	209.6	1,467.0	2,466.0	11.8	29.5
150	488.3	3,489.5	5,955.5	12.2	24.4
160	934.4	7,113.5	13,069.0	14.0	23.3
170	1,548.8	12,416.0	25,485.0	16.4	23.4
180	2,195.2	19,220.0	44,705.0	20.3	25.4
190	2,624.0	24,096.0	68,801.0	26.0	28.9
200	3,475.2	30,496.0	99,297.0	28.6	28.6
210	4,143.3	38,117.5	137,414.5	33.1	28.3
220	5,191.0	46,876.5	184,291.0	35.6	29.7
230	6,230.0	57,105.0	241,396.0	39.2	30.5
250	7,348.0	135,780.0	377,176.0	42.1	28.0
a 260			444,000.0		
a 270			512,000.0		
a 280			580,000.0		
a 290			650,000.0		
a 300			700,000.0		

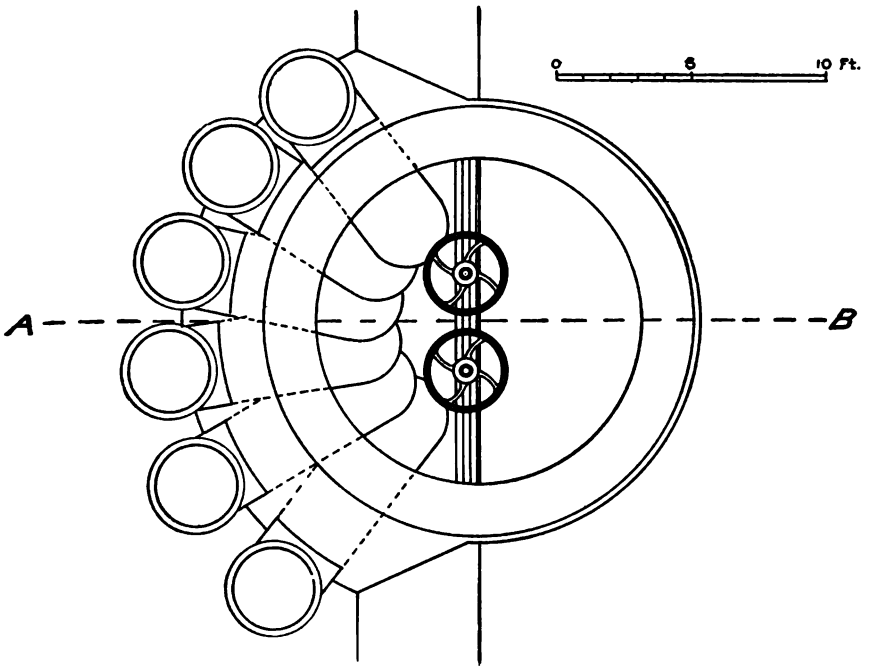
a Estimated.

A SAN CARLOS DAM SITE, LOOKING DOWNSTREAM.

B LEFT ABUTMENT OF SAN CARLOS DAM SITE.



A. INLET VALVE FOR SAN CARLOS DAM.



B. HORIZONTAL SECTION OF MAIN TOWER OF SAN CARLOS DAM, SHOWING ARRANGEMENT OF VALVES.

The area that will be flooded by the construction of a dam at the Narrows will be on the Apache Indian Reservation. The question of right of way would be the obtaining of the use of these reservation lands. A plane-table survey of the reservoir site was made by Mr. Cyrus C. Babb, on a scale of 2½ inches to the mile and with a contour interval of 10 feet. From this survey it was found that 587 acres of lands that have been irrigated and farmed by the Indians would be flooded; that of the remaining area, 4,405 acres are irrigable, the remainder, 3,360 acres, being nonirrigable. No improvements have been made by the Indians other than the building of brush fences and houses. The Apache Indian is of a roving nature and does not like to live for a long period of time upon one spot. It is said that when a death occurs in a family the house is abandoned and a new location is selected.

In order to provide for the damage which would be done to these Indian farms, the estimate includes $20,000 for the construction of a new irrigation system for the Indians above the reservoir site. There is as much water available from the Gila River at points between San Carlos and Geronimo as near the agency. Lands in that locality are unoccupied, are of equal fertility, could be irrigated with equal ease, and are on the reservation. If, therefore, a substantial irrigation system should be built for these Indians higher up on the river, and this should be given to them in lieu of their primitive and deficient systems that now exist, it is considered that the treatment would be fair.

When the Gila Valley, Globe and Northern Railway built through the reservation they paid the Indians at the rate of $40 an acre for the irrigated lands that were used for right of way and in addition gave the tribe in general $8,000. These Indians are industrious and anxious to work for wages whenever opportunity is offered. They built the greater portion of the railroad through their agency. The work on the dam would extend over a period of two years or more, and the Indians may be given much employment in connection with this construction. It has been found in Mexico that as the water is run off from a reservoir crops may be raised upon the uncovered lands, which have been completely saturated by the retiring water. These lands are found to be most productive. The Indians of San Carlos would have the opportunity of raising crops upon marginal lands and would doubtless avail themselves of this opportunity.

The agency grounds and military post were surveyed in detail on a scale of 200 feet to the inch, with 5-foot contours. The essential features of this map have been reproduced on Pl. XXVIII.

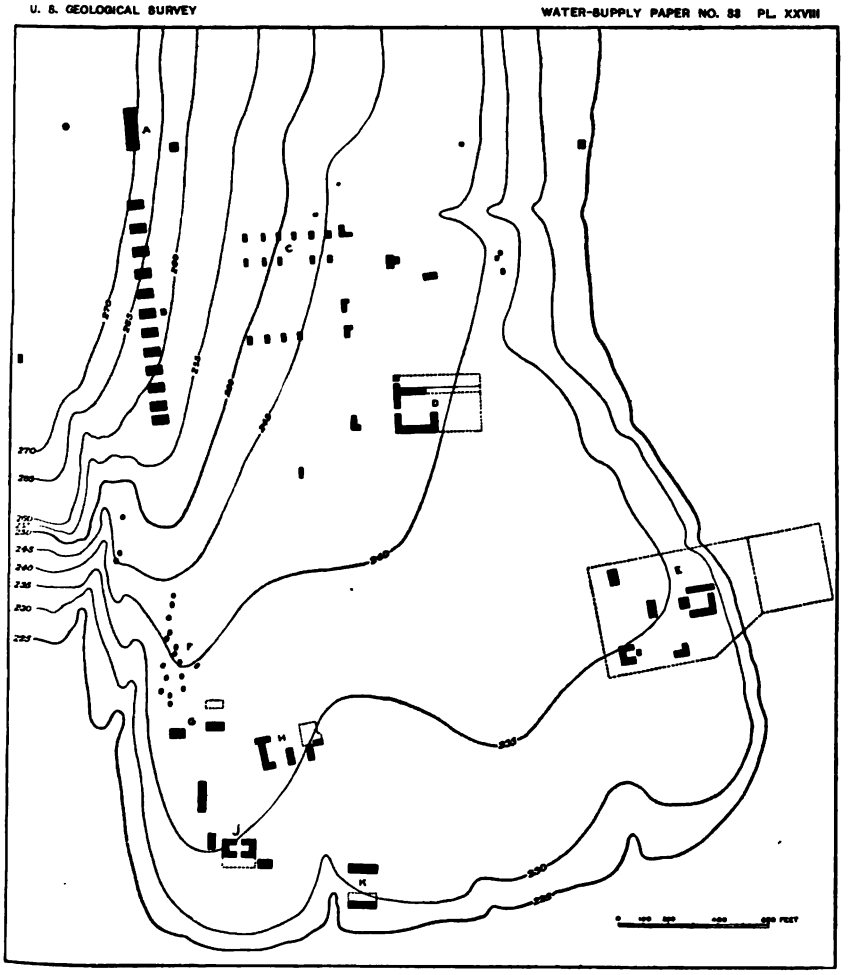
While the elevation of the spillway at the dam is 130 feet above the bed of the stream, the flood line of the reservoir must be considered as being at the maximum elevation of the water passing over the weirs, or approximately 145 feet above the bed of the stream, or 245 feet

above the datum of the contour surveys. This contour, whil
would not include all the buildings of the military post and of
Indian agency, would cover so great a portion of the grounds tha
remainder would be practically useless.

The agency and the post are both exceedingly dilapidated and
It has been proposed that the entire agency be moved to a n
desirable location about 8 miles above, on the San Carlos Ri
where, in fact, the greater number of the Indians are located.
handsome new school building, which has been provided for in re
appropriations, will not be located at the old agency, but at this p
higher up on the San Carlos. There is a stone school building, s
house, and blacksmith shop at the agency. The officer's quarter
adobe, the post trader's building is a frame structure, and there
twenty frame barracks. The quartermaster's department is a s
of sheds, and the remaining buildings are either adobe or of ro
lumber. They are all one-story structures except the schoolho
and are of a very ordinary type. There is a military ice and pu
ing plant and an agency flour mill, which would be flooded by
reservoir.

After a careful consideration of all the buildings, and a discu
of the situation on the ground with officers in charge and t
familiar with the value of the property, a total price of $60,0
considered as sufficient to provide for all damages done. This
has been included in the estimate. In view of the probable mo
of the agency to another location and the possible abandonme
the military post, and considering the general state of dilapid
which prevails, this figure of $60,000 for the building of a new
is considered as liberal.

As will be seen by reference to the map of the San Carlos rese
site, the Gila Valley, Globe and Northern Railway enters the rese
basin near its head, on the Gila River, and passes up the valley o
San Carlos River, a total distance of 5.75 miles in the reservoir
This railroad was built in the fall of 1898. A better location fo
road, away from the river, was recommended by the locating e
neer. It provided for the crossing of the neck of land between
Gila and the San Carlos. The location of this line is indicated b
topography on the reservoir map (Pl. XXVII). The railroad cou
changed from its present location, beginning at a point 2 miles a
the Gila River bridge and crossing the Gila at that point, passing
a divide on the point of land mentioned above at an elevation o
than 200 feet above the bed of the stream, crossing the San Car
miles above the San Carlos station, and joining the present line a
last-named point. The length of new construction would be 5 m
The roadway would cost about $8,000 per mile, or a total of $40
The material for the roadbed would cost, approximately, $4,000
mile, but could be moved from the old location. There would



CONTOUR MAP OF THE GROUNDS OF THE SAN CARLOS INDIAN AGENCY AND MILITARY POST, SHOWING LOCATION OF BUILDINGS.

A, hospital; building of adobe and military tank above it. *B*, adobe buildings occupied by the officers. *C*, frame buildings used as barracks. *D*, adobe buildings used as stables. *E*, school grounds; buildings mainly of adobe. *F*, huts or wigwams used by the Indian police. *G*, guardhouse. *H*, trader's store. *I*, stone warehouses. *J*, offices of the United States Indian agency; built of adobe. *K*, shops and stables built of stone.

saving of 4 miles in distance in the new line over the old, which should compensate for the moving. There would be two bridges to move, at an approximate cost of $10,000.

The Gila bridge contains thirty-three 16-foot bents and three small spans. The San Carlos bridge has thirty-four 16-foot bents. The total cost of moving this railroad has been estimated at $50,000. As all the material for the construction of the dam that will be shipped to San Carlos will have to pass over this railroad, including about 25,000 barrels of cement, and as the railroad will be shortened 5 miles without any serious additional grade and removed from a valley of two torrential streams, it would seem that this change of location might be readily arranged. The reason the railroad was placed in its present location was to enable it to reach the post and agency and secure that trade. With the agency removed, there would no longer be the occasion for its present location.

Estimate, San Carlos dam.

Rubble masonry, laid in concrete, 94,730 cubic yards, at $6	$568,380.00
NOTE.—With sand cement, at $4.68 per barrel, or $4.28 per cubic yard. (See Duryee's report.) This figure is based on half of the mass being large rock and half concrete.	
Excavation foundation, pumping, etc	150,000.00
1 semicircular tower, of concrete, 13,632 cubic feet, at 50 cents	6,816.00
1 tower, same diameter inside, 60 feet high, 4,238 cubic feet, at 50 cents	2,119.00
2 tower houses, including the semicircular base of concrete, at $750 each	1,500.00
10 inlets for towers, at $500 each	5,000.00
2 balance valves, at $1,000 each	2,000.00
2 balance valves, at $750 each	1,500.00
610 linear feet of footbridge, at $10	6,100.00
5 miles of railway, moved, at $10,000 per mile	50,000.00
New irrigation system above the Indian agency	20,000.00
Damage to agency and post buildings	60,000.00
Low water diversion tunnel	10,000.00
Wooden crib diversion dam at head of irrigation canal	20,000.00
	903,415.00
Contingencies, 10 per cent	90,341.00
Engineering, 5 per cent	45,170.00
Total	1,038,926.00

Total number of acre-feet stored is 241,396, at a rate of $4.30 per acre-foot.

GUTHRIE RESERVOIR.

The Guthrie reservoir site is situated in Graham County, Arizona, about 30 miles northeast of the town of Solomonville, on the Gila River. The dam site shown on Pl. XXX is about 1 mile above the Coronado Ranch House, in what is known as York Canyon. This is approximately 4 miles above Guthrie and 13 miles below Duncan. The canyon is about 2,000 feet long, opening both above and below into broad valleys. The survey was made for a 140-foot dam, as a natural

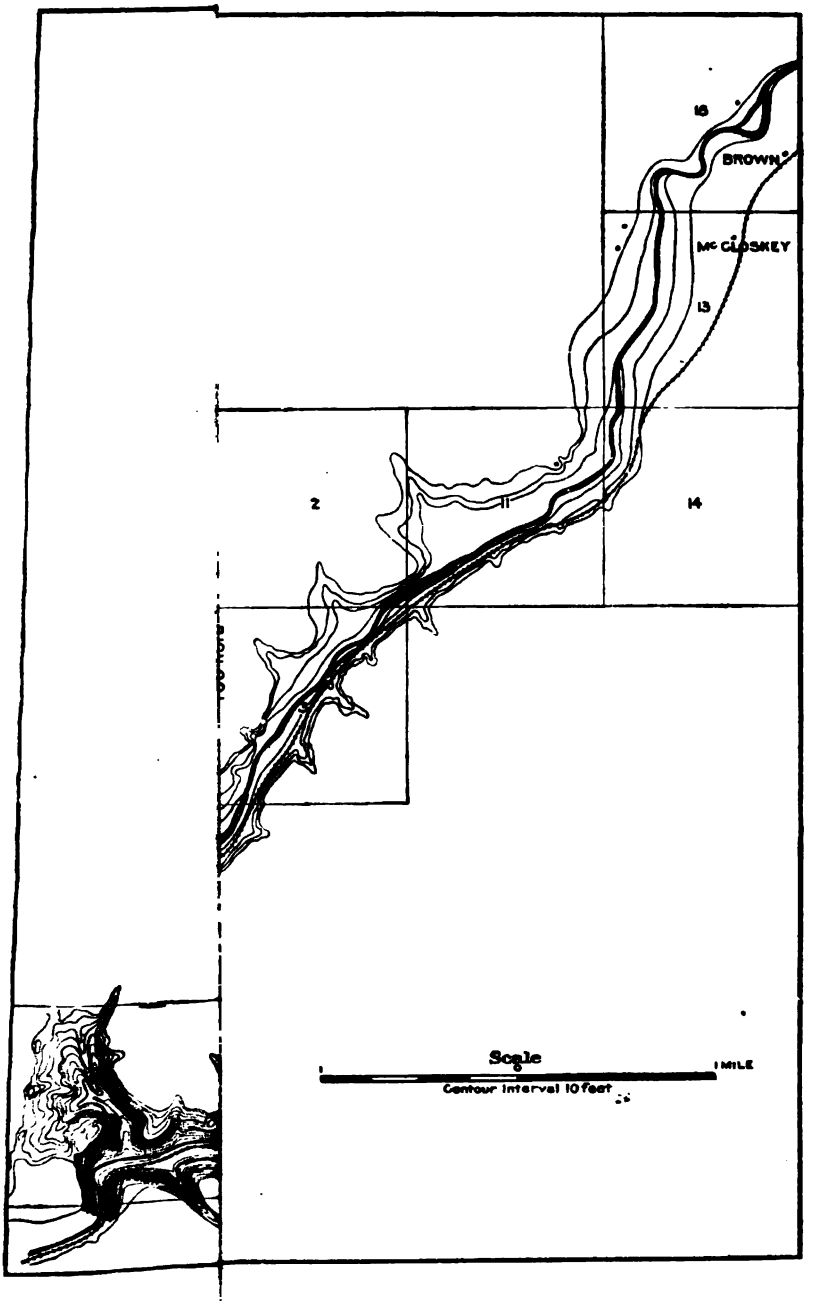
spillway occurs one-half mile east of the dam site, the lowest elevation of which is 130 feet. The main wagon road through the valley passes directly through this spillway. The opening varies from 200 to 300 feet in the bed of the canyon and from 800 to 900 feet in width at an elevation of 140 feet above the stream. The cliffs of the canyon are composed of volcanic rock, and quarries could be located at an elevation above the dam site. No borings for bed rock have been made at this point, because of the lack of funds, and also on account of its remoteness from other portions of the work. The walls of the canyon indicate varying conditions of lava flow. They are shattered, and in some instances there are strata of hard rock overlying cobbles and clay. It is not probable that the rock could be quarried in great quantities or in blocks, and it would be difficult to get good abutments. It has been exceedingly contorted and crushed at an elevation of about 40 feet above the bed of the river.

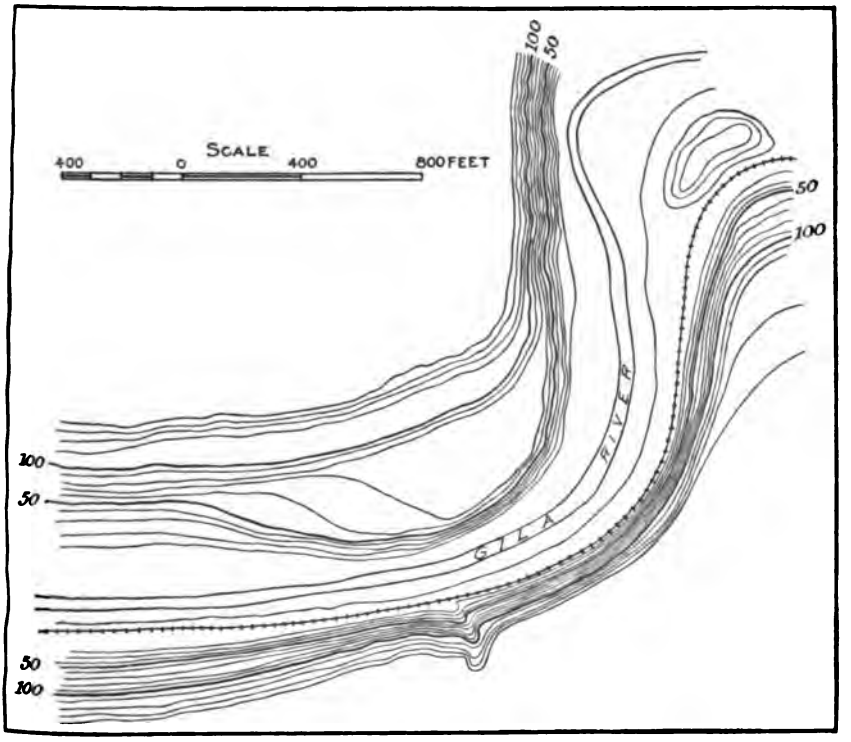
The survey of the reservoir site was made by Mr. Cyrus C. Babb, hydrographer, on a scale of 1 mile to 2½ inches (Pl. XXIX). The 140-foot contour runs within three-quarters of a mile of the town of Duncan. It is probable that the type of dam which would be constructed at this point, if one should be built, would be of a rock-fill type or possibly of earth. The basin of the reservoir contains no irrigated agricultural land, but it would appear to be possible to irrigate a portion of this valley. The New Mexico and Arizona Railroad, which is a narrow-gage road running to Morenci, Arizona, passes through the entire length of this reservoir site and through the dam site. The side of the reservoir site on which the railroad would have to be built is rough, and the cost of construction would be at least $20,000 per mile. Three large tributaries of the Gila—the San Carlos, the Gila Bonita, and the San Francisco—join the river below this point, so that the water supply would be considerably reduced. It was not necessary to prepare estimates on this dam site, but owing to its probable future value for irrigation purposes near Solomonville and Florence, it is recommended that the site be reserved for irrigation purposes. The capacities of this reservoir, with varying intervals, above the bed of the streams at the dam site are given in the following table:

Table of capacities, Guthrie reservoir.

[Capacities calculated by averaging each two sections and multiplying by 10.]

Contour.	Area.	Capacity of each section.	Total capacity.	Contour.	Area.	Capacity of each section.	Total capacity.
	Acres.	*Acre-feet.*	*Acre-feet.*		*Acres.*	*Acre-feet.*	*Acre-feet.*
10	14	70	70	80	1,875	16,530	46,705
20	45	295	365	90	2,383	21,290	67,995
30	154	995	1,360	100	2,844	26,135	94,130
40	390	2,720	4,080	110	3,311	30,775	124,905
50	699	5,445	9,525	120	3,692	35,365	161,270
60	1,000	8,495	18,020	130	4,696	43,290	204,560
70	1,431	12,155	30,175	140	5,552	51,240	255,800


18
BROWN
Mc CLOSKEY
13
2
11
14
Scale
1 MILE
Contour interval 10 feet



CONTOUR MAP OF GUTHRIE DAM SITE.

QUEEN CREEK RESERVOIR.

Queen Creek rises in the mountains to the westward of the Silver King mining camp, in Pinal County, Arizona, and flows in a general southwesterly direction, leaving the mountains below a point known as Whitlow's ranch, approximately 18 miles north of the Buttes. In ordinary years it loses itself in the desert north of the Gila River Indian Reservation. The reservoir site was surveyed with a plane table to a height of 140 feet above the bed of the stream at the dam site and contoured in 10-foot intervals (Pl. XXXI). The following table gives the capacity of this reservoir with varying heights of dam:

Area and capacity of Queen Creek reservoir.

Contour.	Area.	Capacity.	Contour.	Area.	Capacity.	Contour.	Area.	Capacity.
	Acres.	*Acre-ft.*		*Acres.*	*Acre-ft.*		*Acres.*	*Acre-ft.*
2,060	8	40	2,110	279	5,425	2,160	757	30,795
2,070	22	190	2,120	358	8,600	2,170	894	39,050
2,080	52	580	2,130	445	12,605	2,180	1,019	48,615
2,090	112	1,380	2,140	538	17,520	2,190	1,091	50,665
2,100	209	2,985	2,150	630	23,360			

A dam of the rock-fill type was estimated upon in 1895 to cost $221,000. The total area of the drainage is 142.5 square miles.

Observations on the discharge of Queen Creek were commenced in 1895, at the time of the first investigation for a water supply for the Gila River Indian Reservation. A gage rod was then placed and a gaging station established at Whitlow's ranch, at the dam site of the Queen Creek reservoir site. During the year 1896 an observer was employed and located at this station. At the time of the establishment of the station there was a slight permanent flow, averaging about 2 second-feet, which next year failed. The principal water supply of this creek consists of floods of one or two days' duration, occurring immediately after a rainfall in the basin. On this account, in order to obtain an accurate determination of the discharge, an observer has to be constantly located at the station to measure the discharge and to record its duration of flow. Such a system was employed during 1896 and until April, 1897.

The monthly discharge at this station for 1896 is published in the Eighteenth Annual Report of the United States Geological Survey, Part IV, page 295. The total discharge for the year was 10,887 acre-feet. The daily observations for 1897 are published in the Nineteenth Annual Report, Part IV, page 417. The floods were measured as they occurred, and it is assumed that they lasted twelve hours each. On this basis the total discharge to April 6, 1897, was 8,020 acre-feet.

The total discharge for the year has been estimated in the following manner, and is only roughly approximate. A rainfall record has been kept at Pinal ranch, within the drainage area, from 1895 to the pres-

ent date, inclusive. The total precipitation for 1897 was 23.23 inches. For the period from January to March, inclusive, during the time in which measurements of discharge on the creek were made, the precipitation was 14.21 inches. A proportion was, therefore, made—14.21 is to 23.23 as 8,020 is to total discharge for the year. Working out this proportion gives a total discharge of 13,110 acre-feet.

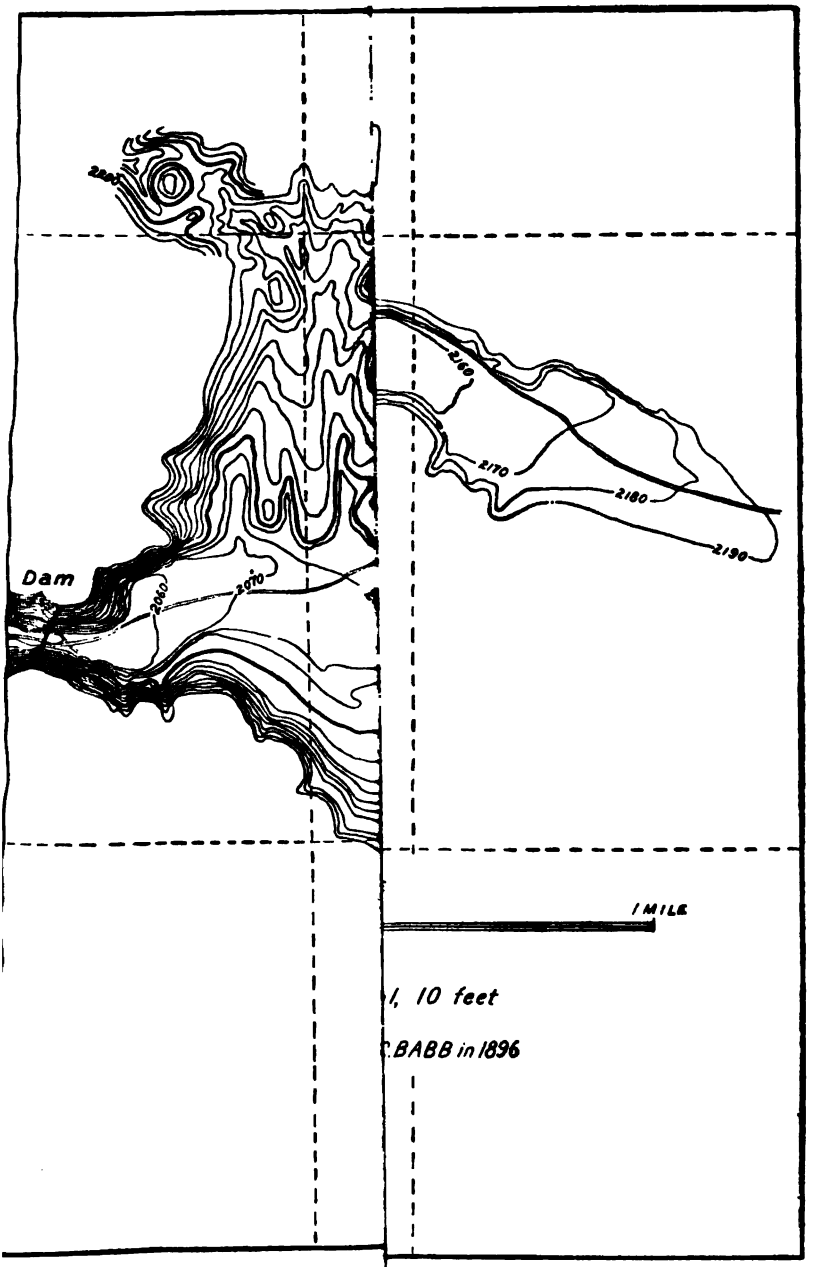
An observer was employed at this station for July, August, and September, 1898. He recorded the heights of floods on the gage rod as they occurred. From this record, in connection with the cross sections which were measured, an estimate of the discharge of the creek was made. These observations are reported in Water-Supply and Irrigation Paper No. 28 of the United States Geological Survey, page 132. The discharge for these three months has been computed as 5,140 acre-feet, including the one flood occurring in December of that year. The creek was reported dry from the 1st of March until the time the observer assumed his duties, and from September to the measured flood, December 18. One flood occurred, however, in January or February, 1898, of which no record was kept, but the quantity was not notably large. It is reported by people located in the basin that the year 1898 was characterized by an exceedingly small flow of the creek. The total discharge for the year is assumed as 6,000 acre-feet. It is probable this amount was not exceeded.

The old gaging station was reestablished in December, 1898, and an observer employed to record any floods occurring. Meter measurements were not made, but gage records were taken on both the original gage and a slope gage placed 431 feet above and referred to the same datum. Cross sections of each flood were measured. From this data the discharges of the creek were computed by means of the Kutter formula. From these computations for the period from January 1 to August 11, 1899, the discharge is found to be 12,527 acre-feet.

Summary, total annual discharge of Queen Creek at Whitlow's ranch, Arizona.

Year.	Acre-feet.
1896	10,887
1897	13,110
1898	6,000
1899, Jan. 1 to Aug. 11	12,527

As it has been shown that 10,875 acres, requiring 20,000 acre-feet of water, are needed at once for the Indians who are on or near the Gila River Indian Reservation, and as an ultimate consumption of 40,000 acre-feet is estimated as a possible future need and this amount accepted as the basis of this report, it is obvious that Queen Creek is not able to supply the full demand, either present or prospective.



1, 10 feet

C. BABB in 1896

BED ROCK AT DAM SITE.

A diamond core drilling outfit was sent to Queen Creek on April 17, 1899, and the work was completed on May 20, 1899. It was found difficult to drive the pipe at this point, owing to the presence of numerous bowlders in the covering of the bed rock. The pipe was frequently bent and it was often found necessary to place dynamite in the hole, raise the pipe a few feet, and explode the powder before the pipe could be driven to bed rock. There were 11 holes put down, their relative location being shown on Pl. XXXII, *A*. The elevations at each of these is given in the list below. At a point on the figure marked "Gage" is the upper gage rod, its zero being at an elevation of 2,041.7 feet. At the point near this, marked "Iron," is the northwesterly iron gad, put at an elevation of 2,049.9 feet. Opposite this is the northeastern iron gad, at an elevation of 2,060.6 feet. At the point marked "B. M." is one of the bronze tablets of the Geological Survey, placed at an elevation of 2,055.1 feet.

Borings at Queen Creek.

Hole.	Surface elevation.	Bed-rock elevation.	Depth.	Depth bored into rock.
	Feet.	*Feet.*	*Feet.*	*Feet.*
1	2,050.0	2,013.0	37.0	7.5
2	2,051.4	2,017.4	34.0	3.0
3	2,053.4	2,027.4	29.0	6.0
4	2,050.6	2,018.6	32.0	4.0
5	2,049.7	2,021.4	28.3	6.2
6	2,050.5	2,011.0	39.5	4.2
7	2,049.5	2,017.5	32.5	7.0
8	2,050.2	2,015.2	35.0	7.0
9	2,050.5	2,022.3	28.2	3.0
10	2,050.2	2,007.7	42.5	1.5
11	2,047.3	2,023.8	23.5	5.5

There is a United States Geological Survey bronze bench-mark tablet on the left bank, in line with the upper row of holes, set in the rock about 5 feet above bed of stream. Elevation, 2,055.7 feet.

The bed rock was found to be a uniform, heavy, volcanic product, having a specific gravity of 2.49, or a weight of 155.5 pounds per cubic foot. Its strength to resist crushing was greater than the capacity of the testing machine. A core three-fourths of an inch in diameter would not crush under a pressure of 1 ton. Further description of the Queen Creek dam and reservoir site may be found between pages 43 and 52 of the report on the irrigation investigation for the benefit of the Pimas and other Indians on the Gila River Indian Reservation, Arizona, by Mr. Arthur P. Davis, hydrographer, in Senate Document No. 27, Fifty-fourth Congress, second session.

CEMENT.

By Edward Duryee.

Investigations were made under instructions from Mr. J. B. Lippincott, in order to ascertain means of lessening the cost of Portland cement in the construction of dams on the Gila River in Arizona. Owing to the remoteness of these proposed dams from lines of transportation, the expense of bringing cement to the sites makes a notable addition to the cost over construction elsewhere, and it is therefore of great importance to reduce the quantity of cement to the smallest allowable amount.

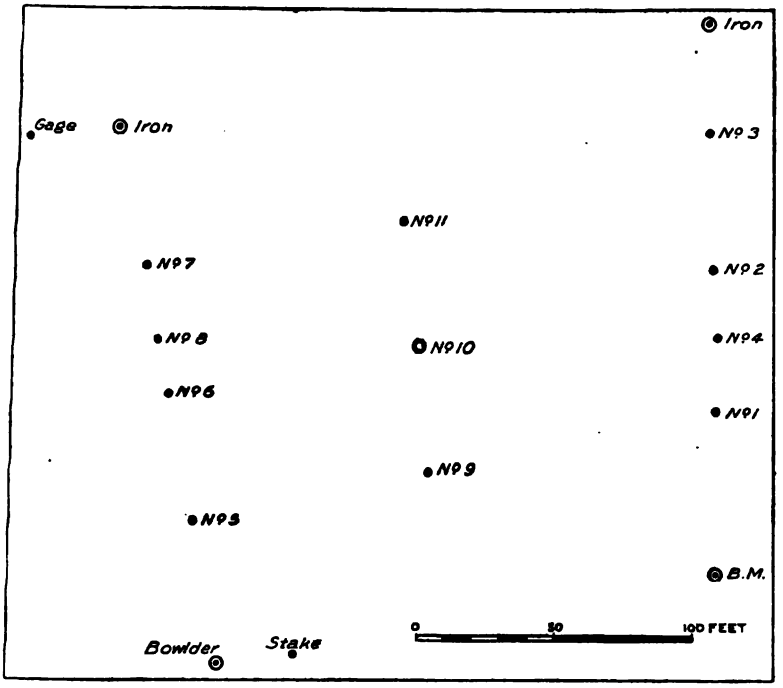
Portland cement is considered an essential element in the construction of dams subject to severe and sudden strains due to floods. It is valuable not only in giving great strength and homogeneity to the structure, but also because of the fact that exposure to moisture, which deteriorates many materials, serves to increase the strength of Portland-cement mortars. It is thus being largely used for this purpose. For example, the new dam under construction on the Nile at Assuan will require 3,000,000 barrels of Portland cement, costing, in round numbers, $12,000,000.

The investigation of cement for the Gila River dams has been along three lines: (1) To ascertain whether by unusually fine grinding of the cement its strength can be appreciably enhanced and the quantity correspondingly reduced; (2) whether it is feasible to use the rocks found at the dam sites for making a sand cement; (3) whether Portland cement can be economically made at these sites.

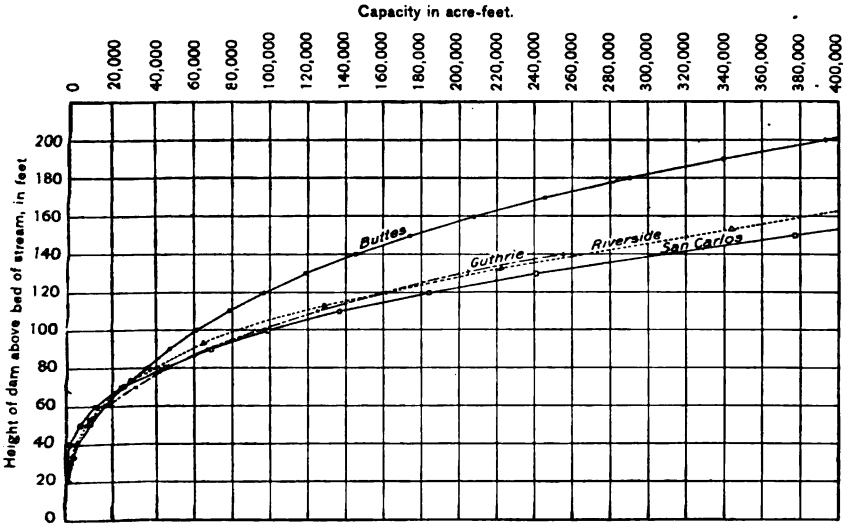
SAND CEMENT.

Sand cement is a term applied to a mixture of cement and sand ground together in a dry state to an impalpable powder. As a rule Portland cement and quartz sand are the materials thus used. This mixture is then used with ordinary sand and gravel, as in the customary practice. The proportion of pure cement is thus considerably reduced, but the strength and durability of the concrete has been found to be nearly as great as that made with the undiluted cement. The explanation offered for the remarkably good results obtained with sand cement when used with ordinary coarse sand is that the voids in the coarse sand are nearly filled with the finely ground sand. The grains are thus bonded together and to the coarse sand by the uniformly diffused particles of the fine cement. The amount of voids in the ordinary sand, in other words, is greatly reduced by the fine sand, fulfilling the requirement for a strong mortar that it is necessary to be of dense character, the grains being of such graduated size and so well mingled as to afford the maximum contact of the surfaces of the particles.

In sand-cement mortar the grains of sand are extremely minute,



A. LOCATION OF BORINGS AT QUEEN CREEK DAM SITE.



B. CAPACITY CURVES OF THE PROPOSED RESERVOIRS ON GILA RIVER, ARIZONA.

the mixture being so fine that only 5 per cent residue is left on a screen of 200 meshes to the linear inch or 40,000 meshes to the square inch. The great density thus obtained contributes to the impermeability to water and increases the compressive strength and load-bearing capacity, thus rendering the mass of value for constructing foundations, dams, and sea walls.

In the tests made in this investigation a rock known as pearlite, an acidic lava or rhyolite from the Buttes dam site, was used, and also samples of quartzite from the San Carlos dam site. These were chosen because of the abundance of these rocks at the localities named and their superior hardness. The Portland cement used was that manufactured at Colton, California, this being made nearest to the place where it will be used and being sold at a lower price than other Portland cement in the local market. All of the tests were made with the same sample of cement, portions of this being taken for the several mixtures with crushed pearlite and quartzite. The sand used with the foreign cement in making sand cement was clean beach sand from dunes along the coast.

TESTS OF SAND CEMENTS.

Results of the tests of the sand cements and comparisons with otner mixtures are given in the following table. In each case the crushed pearlite was mixed with an equal weight of cement, and the mixture was ground in a mortar until it all passed through a screen having 200 meshes to the linear inch. The same method was pursued with the quartzite from San Carlos, thus making sand cements composed of equal parts of Portland cement and pulverized rock ground to an exceedingly fine condition.

The coarse sand used in making the mortar with the sand cement and with the pure (Portland) Colton cement was of the ordinary grade of fineness used for making cement tests. It was screened from ordinary gravel, all residue on the 20-mesh screen being rejected and all left on the 30-mesh screen being retained.

The briquettes for testing were made according to the specifications recommended by the American Society of Civil Engineers. After the briquettes were made they were kept under a damp cloth for twenty-four hours, then placed in vats of water, where they were left until the time for breaking arrived, namely, seven days or twenty-eight days. The fine grinding and diluting of the Portland cement with fine sand did not materially affect the time of hardening or setting. The beginning of the setting process of the ordinary Colton cement mortar, or initial setting, was thirty-three minutes, and the time of final setting was eighty-five minutes. This applies to samples Nos. 3, 4, and 9 of the following list. The corresponding periods for the sand cement were thirty and eighty minutes. The cement mortar continues to harden and increase in firmness for a year or longer.

Results of tests of Portland sand cements.

No.	Material.	Sand.	Portland cement to sand.	Fineness.			Water.	Strength.	
				50 mesh.	100 mesh.	200 mesh.		7 days.	28 days.
				Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Lbs.*	*Lbs.*
1	Colton and Butte pearlite, 1 to 1	2	1 to 5	0.00	0.00	0.00	10	80	300
2	Colton and San Carlos quartzite, 1 to 1	2	1 to 5	.00	.00	.00	10	90	345
3	Colton, regular	2	1 to 2	.42	7.20	33.20	10	170	385
4	do	3	1 to 3	.42	7.20	33.20	10	140	240
5	Colton, fine ground	2	1 to 2	.00	.00	(a)	12	370	465
6	do	3	1 to 3	.00	.00	(a)	12	170	260
7	Colton and Butte pearlite, 1 to 1	3	1 to 7	.00	.00	.00	10	75	155
8	Colton and San Carlos quartzite, 1 to 1	3	1 to 7	.00	.00	.00	10	55	185
9	Colton, regular	0	1 to 0	.42	7.20	33.20	18	615	660
10	Imported	0	1 to 0	.80	7.80	29.33	18	345	525
11	Imported and sand, 1 to 1	2	1 to 5	.00	.00	.00	10	115	190
12	do	2	1 to 5	.00	.00	(a)	10	125	185
13	do	3	1 to 7	.00	.00	(a)	10	55	90
14	do	3	1 to 7	.00	.00	.00	10	90	140
15	Imported, regular	2	1 to 2	.80	7.80	29.33	10	210	270
16	do	3	1 to 3	.80	7.80	29.33	10	120	175

a Some left on 200-mesh screen.

NOTE.—The above cement stood the boiling test for free lime satisfactorily.

Comparison of test No. 3 with No. 5, and of No. 4 with No. 6, shows that increased fineness of grinding very materially increases the strength and sand-carrying capacity of cements. The ordinary Colton cement of tests No. 3 and No. 4 was ground finer than commercial Portland is usually ground. Recent improvements in mills for grinding render possible a reduction in size of cement grains at a cost which is small when compared with the great increase in the value of the resulting material. Where the freight charges are high, as is the case at the locations under consideration, it is especially important to take advantage of this improvement, and there is no doubt that if the specifications call for a fineness such that only 1 per cent is to be left on a 100-mesh screen, the manufacturers will respond to the requirements. Engineering specifications have ordinarily allowed a residue of 5 per cent on a 50-mesh screen, although manufacturers have for some years permitted a residue of only 1 or 2 per cent on a 50-mesh screen.

CRUSHING TESTS.

In order to obtain the crushing strength of the various cements and concrete considered, two 1-inch cubes of each were broken. The results given are the averages of the crushing strength of the two cubes. The cubes were allowed to remain thirty days in water and then thirty days in the air.

Crushing tests of 1-inch cubes.

Character of mixture.	Water.	Average crushing strength.
	Per cent.	*Tons.*
Standard Colton cement	18	3.25
Colton cement, 1 part, and ordinary testing sand, 2 parts	8	1.75
Colton cement, 1 part, and marble sand, 2 parts	8	2.38

Crushing tests were also made of 6-inch cubes of concrete after these had been immersed for thirty days in water. The portions of the mixture and the breaking strain in tons are given in the following table. In the mixture the proportions are given by volume and not by weight.

Crushing tests of 6-inch cubes.

Character of mixture.	Breaking strength.
	Tons.
Colton cement, 1 part; ordinary sand, 3 parts; pebbles from gravel, 6 parts	38
Colton cement, 1 part; sand, 3 parts; crushed marble, 6 parts	30
Colton cement, 1 part; sand, 2 parts; crushed marble, 5 parts	20

It is believed that concretes of approximately equal value can be obtained by using cements in the following proportions, measured by volume:

Portland cement, 1; sand, 3; broken stone, 7.
Sand cement, 1; sand, 2; broken stone, 6.

COST OF SAND CEMENTS.

In the Portland-cement concrete made in the proportion of cement 1 part, sand 3 parts, and broken stone 7 parts, it has been found that 270 pounds of cement will be required for a cubic yard of concrete. This, at 2.12 cents per pound, will cost $5.72 per cubic yard.

In the sand-cement concrete of the proportions 1 cement, 2 sand, and 6 stone, 340 pounds of cement would be required for each cubic yard of concrete. This, at 1.2 cents per pound, would cost $4.08.

The saving in the cost of cement to be effected by using sand cement instead of the Colton Portland will be the difference between $5.72 and $4.08, or $1.64 per cubic yard of this concrete entering into the construction of the dam. From the total saving thus realized should, however, be deducted the cost of the plant required for grinding the sand cement.

Concrete blocks composed of the above proportions were crushed at McGill University in 1898, with the following results:[1]

Sand cement, 1; sand, 2; broken stone, 6; water, 20 per cent.
Weight per cubic foot, 154 pounds. Crushing load, in pounds per square inch: Seven days, 521 pounds; twenty-eight days, 639 pounds; sixty days, 670 pounds.

A concrete of German Portland of the proportions of 1 cement, 2 sand, 6 broken stone, and 20 per cent water stood a load of 728 pounds per square inch in twenty-eight days, and one of the same proportions made from English Portland stood 698 pounds in twenty-eight days.

Tests for crushing strength on 6-inch cubes of concrete, made of 1 part sand cement, 2 sand, and 3 parts gravel, were made on concrete that was taken from the bucket just as it was ready to be laid in the foundation of the Cathedral of St. John the Divine, in New York City. Each result is the average of the crushing strength of four separate cubes, made under exactly the same conditions at different periods:

	Pounds.
7 days old crushed at	77,162
14 days old crushed at	83,225
30 days old crushed at	92,465

Approximate cost of plant for making sand cement; capacity, 240 barrels per twenty-four hours.

Crusher (required also for crushing rock for concrete)	$2,000.00
Mill for coarse grinding	2,000.00
Tube mill for finishing	2,500.00
Engine and boiler	1,500.00
Setting up machinery	1,000.00
Buildings and bins	1,000.00
Total	10,000.00
Cost of mill, per barrel of cement	.20
Add for concrete making a power mixing machine	1,500.00

In making concrete, if a good quality of stone be used, and the rock be crushed so as to be well graduated as to sizes, thus securing a minimum of voids, the compressive strength of the concrete increases as the proportion of stone increases and as the volume of voids between the stone decreases, and decreases as the proportion of sand in the mortar increases. The rule, therefore, holds that, to secure the greatest strength, mix the maximum quantity of stone with a minimum of sand mortar sufficient to bond the stone together, the sand mortar being rich in cement. An extensive bed of exceptionally good sand for mortar was found near the Buttes, the grains graduating in size from very small to large sizes. It shows only 35 per cent of voids, while the standard cement-testing sand used in laboratories has 45 per cent of voids.

[1] From Canadian Architect and Builder, 1899.

A large tube mill will grind 10 barrels of sand cement per hour to the requisite degree of fineness, at an estimated cost of 20 cents per barrel. The cost of power for grinding is calculated at 3 cents per horsepower per hour at the dam site.

Cost of sand cement with Portland cement at $8 per barrel.

One-half barrel Portland	$4.00
One-half barrel crushed and coarse-ground quartzite	.18
Grinding same in a tube mill	.20
Royalty on account of sand-cement patent	.05
Total cost of sand cement per barrel (375 pounds)	4.43

The cost of sand cement per pound, quartzite being used as the source of the sand cement, would therefore be 1.2 cents.

The cost of the mill per barrel of cement, 20 cents, is not included in the above.

It is estimated that the cost per barrel of Colton Portland cement, delivered at the dam site will be $8. This, for 375 pounds weight cement, would make the cement cost 2.12 cents per pound.

USE OF ROCKS AT THE DAM SITES.

For the purpose of ascertaining whether the rocks at the dam sites could be used in the manufacture of Portland cement the localities were visited and samples were obtained of those rocks which occurred in sufficient quantities to furnish a supply necessary for manufacturing the large amounts of cement needed. In looking for the raw materials it must be borne in mind that, chemically considered, Portland cement consists of a compound of tricalcium silicate and dicalcium aluminate, accompanied by small percentages of ferrate and sulphate of lime and traces of alkalies. It is made by grinding and burning together either natural or artificial mixtures of carbonate of lime and silicate of alumina. Limestones, chalks, or marls usually furnish the carbonate of lime, and clays are the ordinary source of the alumina and silica. The mixtures are burned at a high temperature to a blackish clinker of a semivitrified character. After cooling, this clinker is reduced by grinding to an impalpable powder, in which form it is known by the generic name of Portland cement.

ROCKS AT RIVERSIDE DAM SITE.

Limestone (No. 3 in the following table) was obtained near Riverside, on the road to the Pioneer mill, where it is found in large quantities along the roadside. The rhyolite (No. 4 in the following table) was found 2 miles south of the Riverside site. It offered the closest approach to a suitable silicate of alumina that could be found.

The source of elements of silica and alumina in the crude materials should, however, be sedimentary in character, not igneous or metamorphic. The analysis justified a trial mixture, and therefore one was calculated and made, but on burning the materials failed to effect the requisite combination for a Portland cement. Too large a percentage of the silica was in the free or uncombined condition. Fuel was not to be found near the Riverside site, and the manufacture of cement at this place is considered impracticable.

ROCKS AT SAN CARLOS DAM SITE.

The limestone from San Carlos site (No. 2 in the following table) was found to be admirably adapted to the purpose of the dam construction on account of its good specific gravity (which was 2.7), freedom from flaws, and siliceous character. It occurs in vast quantities, forming the abutments at the dam site. It forms bluffs, extending for several hundred feet, well located for quarrying. Large masses may be embedded in the concrete, care being taken that they be laid irregularly in the mass of the dam, and are well placed so as to bond into a monolith.

Analyses of rocks from the vicinity of the dam sites.

[Chemical composition, in percentages.]

No.	Name.	Color.	Locality.	Sp. gr.	Carbonate of lime, $CaCO_3$.	Carbonate of magnesia.	Silica (SiO_2).	Alumina and ferric oxide.	Moisture.	Lime per cent in the carbonate of lime.
1	Limestone.	Gray	San Carlos	.....	96.65	0.00	1.4	1.3	0.65	54.124
2	do	Pink	do	2.709	55.92	31.00	3.7	6.0	1.00	31.315
3	do	Blue	Riverside	.....	93.10	0.00	4.7	1.4	.....	52.136
4	Rhyolite	White	do	1.541	9.60	.....	60.9	12.6	16.90	5.376
5	do	Pearl	Buttes	2.361	.....	.....	.....	.....	.....	.....
6	Limestone.	Blue	Queen Creek[a].	2.81	90.10	0.00	4.1	5.8	.....	.....
7	do	Gray	do	2.678	55.50	0.00	34.6	1.3	.....	31.08

[a] From about 1¼ mile above dam site.

The analysis of the gray or bluish limestone (No. 1 in the above table) shows from its freedom from magnesia and the small percentage of free silica that it is possible to make a Portland cement with it, provided a suitable clay can be found to furnish the requisite elements of silica, alumina, and ferric oxide.

FUEL.

An extensive but undeveloped deposit of bituminous coal is located about 17 miles from the San Carlos dam site. There is a wagon trail to within about 6 miles of the coal beds, but after leaving the wagon trail the only means of access was found to be a bridle path over the

hills. About ten years ago numerous prospectors' locations were made in the district, and shafts were sunk at a sufficient number of localities to prove the deposit to be of considerable extent. Most of the shafts have become filled with débris, but several were entered to depths of 15 to 30 feet. They showed the body of coal to be in beds having a dip of about 60°, the beds being from 5 to 10 feet in thickness, not of solid fuel, but showing seams of good coal interlaid with seams of slate and waste. In the bottom of the deepest shafts was found a good body of coal in a solid bed perhaps 5 feet thick. It was reported that at the time the prospecting was done on the claims some 30 tons were transported by wagons to the Southern Pacific Railroad and used in the locomotives, but that the cost of mining and transporting it to the railroad, with the crude means available at the time, was about $20 per ton.

Cement could be burned with the coal. The right to mine the coal for the use of the Government in this work could be secured readily and at a nominal cost. The cost of mining and transportation to San Carlos would, however, be high. In general practice 120 pounds of coal dust are used in burning 1 barrel of Portland cement.

Taking as a basis coal delivered at the dam site at $10 per ton, limestone at 40 cents per ton, and clay at $1.25 per ton, the cost of manufacturing Portland cement at the dam site would approximate $2.75 per barrel. The cost of erecting a plant with an output of 300 barrels of cement every twenty-four hours would be $75,000. Supposing the amount of cement to be required in the construction of the dam to be 50,000 barrels, the cost per barrel, if made at the site, would be approximately as follows: First cost of plant, $75,000; cost of manufacturing 50,000 barrels, at $2.75, $137,500; total cost, $212,500; cost per barrel, $4.25.

With reference to the degree of reliability to be placed upon Portland cement made in new localities, it may be said that the manufacture of this material has been put upon a scientific basis, such that the manufacturing chemist can predict the grade of cement to be made from the given materials and, by means of analyses of various rocks, can calculate suitable mixtures to produce the required result. The uniform system of testing cements recommended by the American Society of Civil Engineers affords a reliable means of determining the intrinsic merits of the product. The old method of buying cements on the reputation of the maker has been succeeded by tests for determining the actual value. Portland cements of American make are being extensively manufactured and are of equal or even superior quality to the foreign-made cements. During the year 1899 it is estimated that 6,000,000 barrels of Portland cement have been used, of which four-fifths were of home manufacture. In spite of this fact, on account of the failure to find suitable clays at the various

localities and also the difficulty of obtaining fuel, it is impracticable to manufacture Portland cement at the dam sites.

It is important, if Portland cement is used at the localities under consideration, that the specifications should require it to be ground so fine that not over 1 per cent residue shall remain on a 100-mesh screen.

Reliable sand cement can be made from the quartzite at San Carlos or the pearlite at the Buttes dam site by grinding with Colton (Portland) cement. A saving will result at the San Carlos dam site of $1.64 per cubic yard by making sand cement on the ground, this being exclusive of the cost of the plant for grinding.

IRRIGABLE LANDS.

The location where the water which is impounded in the reservoir sites on the Gila River would be used is primarily on the Gila River Indian Reservation, which has been described in previous pages of this report, and which contains 357,120 acres of land, the greater portion being irrigable. South of this Indian reservation, intervening between the Southern Pacific Company's railroad and the point where the Gila River leaves the mountains, there are many thousand acres of high-grade agricultural land suitable for irrigation. The climate is adapted to the raising of diversified crops, the grade of the country is uniform and suitable for the application of water, and the soil is exceedingly fertile. The river, which carries a large amount of sediment containing many fertilizing materials, will keep these lands in a state of continuous productiveness. Without water this land is a desert and has no value. That it is of no tangible value in its present condition is proved by the fact that many thousands of acres which have been taken up at previous times under the desert-land act and homestead laws have been permitted to revert to the Government before title was perfected by the settler, even after expenditures had been made on the land.

An examination was made of the records of the United States land office at Tucson to determine what portion of this area outside of the reservation remains public domain. The area in the valley of the Gila between Dudleyville and Riverside was also inspected, as this valley should be segregated for reservoir purposes, and in case of the construction of a reservoir at San Carlos a portion of its water could be used for irrigation in this valley. Nineteen townships were examined, and it was found that 389,211 acres therein are still public domain and that 52,162 acres, lying mostly under the Florence canal—which canal has a very deficient water right—is held in private ownership. There is, therefore, three times the area of irrigable land that can be served on the Indian reservation alone and three times the area of public land off the reservation that can be supplied.

YORK CANYON ON GILA RIVER AT GUTHRIE DAM SITE.

Public and private lands in the vicinity of Florence, Arizona.

Location.	Acres.	
	Government.	Private.
T. 4 S., R. 10 E	18,400	4,640
T. 4 S., R. 11 E	22,720	320
T. 4 S., R. 14 E	21,600	1,440
T. 5 S., R. 5 E	23,040	
T. 5 S., R. 6 E	23,040	
T. 5 S., R. 7 E	22,880	160
T. 5 S., R. 8 E	15,760	7,280
T. 5 S., R. 9 E	13,080	9,960
T. 5 S., R. 10 E	23,040	
T. 5 S., R. 14 E	22,960	80
T. 5 S., R. 15 E	21,000	2,040
T. 6 S., R. 5 E	17,840	5,200
T. 6 S., R. 6 E	12,800	10,240
T. 6 S., R. 7 E	19,440	3,600
T. 6 S., R. 8 E	21,732.06	3,116
T. 6 S., R. 9 E	24,359.26	486.26
T. 7 S., R. 6 E	19,800	3,240
T. 7 S., R. 7 E	22,680	360
T. 7 S., R. 8 E	23,040	
Total	389,211.32	52,162.26

DISTRIBUTION CANALS.

It is not the purpose of this report to definitely locate any canal line across these lands. The construction would be entirely in earth and exceedingly simple. The building of these canals could be readily undertaken by the settlers and by the Indians. The canal line to the Indian reservation would be uniformly in smooth country and with an earth section. A topographic map on a scale of 2 inches to the mile, with contour intervals of 10 feet, has been made of a portion of these valley lands. This map demonstrates the feasibility of building these canals. The Florence Canal, which diverts its water at practically the same point where diversions of reservoir water would occur, runs through the irrigable area under consideration and still further demonstrates the feasibility and the practicability of the building of the canals wherever circumstances may require.

ORGANIZATION OF IRRIGATION DISTRICT.

It is recommended, in case of the construction of any of these reservoirs, that there be appointed a Federal commission to consider the organization under Federal laws of an irrigation district which will include the lands that would be irrigated under this system. This district should be organized with proper officials to handle locally the division and the distribution of the water and for the construction of the delivery canals. The preparation of a code of laws for the operation of this district would be of great importance and should be undertaken jointly by members of the engineering and legal professions.

SUMMARY.

1. The available records of the discharge of Queen Creek at Whitlow's ranch indicates that this stream would not afford a sufficient and reliable water supply for the irrigation of an area as large as is required for the relief of the Indians on the Gila River Indian Reservation.

2. Because of the large amount of annual discharge of water by the Gila River and the high percentage of silt which it contains, it is not advisable to construct a reservoir of small capacity on this stream on account of the rapidity with which it would fill with silt.

3. In case of the construction of any of the dams on the Gila River the cost of putting the foundations down to bed rock is one of the principal elements of expense. This cost would be almost as large if a small dam was built as in the case of a large one.

4. The greatest economy to the Government, whether the relief of the Indian alone is considered, or the general development of the arid lands in the neighborhood of the reservation is taken as a basis, lies in the construction of a large reservoir. It is shown that the Government can build such a large reservoir, give water to the Indians without charging them for it, and sell the remainder of the water impounded at such figure as would rapidly return all the original investment made by the Federal authorities.

5. In the event of the construction of a large dam there will be built up in the valley of the Gila River, where a desert now exists, a community of fully 40,000 souls, and the creation of many million dollars of taxable wealth without permanent outlay on the part of the Government.

6. The cost per acre-foot of storage capacity of the dams as planned in this report at the three principal reservoir sites upon which estimates have been made is as follows:

Cost per acre-foot of water stored.

Location.	Amount.	Cost per acre-foot.
	Acre-feet.	
The Buttes	174,040	$15.19
Riverside	221,138	9.01
San Carlos	241,396	4.30

From this it will be seen that the cost of storing water at the Buttes per acre-foot is 3.5 times the cost at San Carlos, and that the cost at Riverside is 2.1 times the cost at San Carlos.

The capacity of the reservoir, the character of the foundations at the dam site, the conservative and well-known type of dam planned,

and the economy of construction all point to the selection of the San Carlos reservoir site as the place for the construction of the dam.

Perhaps the most notable result of this investigation of the water supply of the Gila River has been the discovery of three large reservoir sites the existence of which heretofore has been unknown. They are the Riverside, the San Carlos, and the Guthrie sites. The relative capacities of these are shown graphically on Pl. XXXII, *B*.

The argument in favor of the construction of a reservoir for the storage of the waters of the Gila River by the United States Government is stronger, perhaps, than for any other project in the country.

1. The Government has expended large sums of money for the introduction of irrigation on the Indian reservations where it is desired to educate the Indian into agricultural habits as a means of his civilization. This is a well-established and wise public policy, and has already been productive of much good, but is always in the nature of an experiment, and more or less difficulty and uncertainty is attendant upon the attempt to induce the Indians to accept this mode of livelihood. In the present case we have a tribe of Indians who have for centuries been engaged in agriculture by irrigation, and who were until recently the only successful irrigators in Arizona. These Indians have been deprived of their water supply through the agency of the white man, directly encouraged by the United States Government. It is an imperative obligation of honor that their supply should be restored to them, and the only practical means of this restoration is by storage on the Gila River. In addition to this, there is held out the certainty that unless this is done these Indians will retrograde from a condition of industry and prosperity to one of mendicancy and vice. Instead of an uncertain possibility of elevating a savage tribe, we are confronted with the necessity of preventing the destruction of a civilization already attained.

2. It is practically certain that the storage of the Gila waters will never be accomplished by private or corporate enterprise for three reasons: (1) The direct financial returns are not sufficient to induce so large an investment of private capital; (2) the unquestionable legal right of the Indians to a large quantity of the water of the Gila River would be a perpetual cloud upon the title to the water in the hands of a private corporation; and (3) the land to be benefited being mainly in public ownership, there is no means under present laws by which a private company could realize the full benefit of their improvements.

3. Arizona being a Territory, the water right is entirely under national jurisdiction; the only material private lien on the right is the right of the Indians, who are wards of the Government, and this is essentially a Government right. The objection applicable in some of the States, that the jurisdiction of water rights is entirely in the hands of the State and would produce a conflict of authority, does not apply here.

4. The Government, being the owner of more land under the canal than can ever be watered by it, can entirely control the appropriation of the values which will be created by the construction of a reservoir and can entirely recoup itself for all expenses incurred, and thus discharge its obligations of honor with no expenditure except the utilization of its own natural resources. It is not a proposition for the Government to expend money for the benefit of private individuals nor of any particular section, and hence is not comparable with river and harbor improvements, although the general benefits are so comparable, as homes will be furnished at low rates to thousands of industrious people, who will come from all parts of the country, and a forbidding desert will be transformed into a rich oasis and a large community will be thus practically added to the domain of the United States.

5. Gila River rises in New Mexico. As the main body of the basin is in Arizona, inter-State complications might arise in the future in case the reservoir were constructed by private or local enterprise. With these questions the National Government only is competent to cope. Thus, from all points of view there is every reason why this reservoir should be constructed by the National Government and no reason why it should not, while it is not only impracticable but eminently inadvisable for private enterprise to carry out the project.

6. Owing to the erratic nature of the Gila River less than 3 per cent of its water near Florence is now being used for irrigation, and the areas now irrigated suffer intensely from summer droughts.

Financial summary of results.

Total water supply to be delivered to the point of diversion from San Carlos reservoir for irrigation each year.....acre-feet..	241,396
Ultimate requirement for Indians .....do....	40,000
Remainder available for irrigation of public domain or private lands .....acre-feet..	201,396
Assume a duty of water of 2 acre-feet or 24 inches in depth used each year on each irrigated acre; this would permit the irrigation of lands outside the reservation to the extent of.....acres..	100,698
There are 389,211 acres of arid public land in the district to be supplied from this system. Assume that the water is given to the Indians without cost to the Government and that these 100,698 acres must pay the total cost of the works, then the necessary charge per acre for the remaining water rights to be sold would be..... It is believed that the public lands with this water right could, at this rate, be sold within a year.	$10.24
If 3,000 Indians have to be fed by the Government at a cost per ration per day of 10 cents, the annual expenses would be.....	$109,500
The capitalization of $109,500 at 4 per cent would represent the practical permanent expense of feeding these tribes. This is equivalent to a permanent Government debt, which would be liquidated by this construction, of.....	$2,737,500

The value of the 100,698 acres of irrigated public lands that would be taxable would be $50 per acre, or a total of	$5,034,900
The saving, without expense to the Government, by irrigation of 20,000 acres of lands belonging to the Indians has been shown to be	2,737,500
Total increase in value, without public expense	7,772,400

There will also be a large increase in value of taxable town property, not estimated upon.

RECOMMENDATIONS.

1. Immediately withdraw from entry all the lands that may be irrigated from this source of supply pending further action by Congress on this matter.

2. Segregate all the reservoir sites on the Gila River that may be used for the irrigation of these lands. The Buttes and Queen Creek reservoir sites have already been segregated for this purpose. The Riverside, San Carlos, and Guthrie reservoirs should also be set aside.

3. Maintain observations on the Gila River

4. Construct the San Carlos dam.

5. Give the Indians the water which they require without charge, the Government to recoup itself for all expenditures from the sale of the remaining water rights.

6. Form a Federal irrigation district for the division of the water, which is to be delivered to the head of the irrigation canals, for the construction of these canals, and for the general administration of the district.

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1895.

Sixteenth Annual Report of the United States Geological Survey, 1894–95, Part II, Papers of an economic character, 1895; octavo, 596 pp.

Contains a paper on the public lands and their water supply, by F. H. Newell, illustrated by a large map showing the relative extent and location of the vacant public lands; also a report on the water resources of a portion of the Great Plains, by Robert Hay.

A geological reconnaissance of northwestern Wyoming, by George H. Eldridge, 1894; octavo, 72 pp. Bulletin No. 119 of the United States Geological Survey; price, 10 cents.

Contains a description of the geologic structure of portions of the Bighorn Range and Bighorn Basin, especially with reference to the coal fields, and remarks upon the water supply and agricultural possibilities.

Report of progress of the division of hydrography for the calendar years 1893 and 1894, by F. H. Newell, 1895; octavo, 176 pp. Bulletin No. 131 of the United States Geological Survey; price, 15 cents.

Contains results of stream measurements at various points, mainly within the arid region, and records of wells in a number of counties in western Nebraska, western Kansas, and eastern Colorado.

1896.

Seventeenth Annual Report of the United States Geological Survey, 1895–96, Part II, Economic geology and hydrography, 1896; octavo, 854 pp.

Contains papers on "The underground water of the Arkansas Valley in eastern Colorado," by G. K. Gilbert; "The water resources of Illinois," by Frank Leverett, and "Preliminary report on the artesian waters of a portion of the Dakotas," by N. H. Darton.

Artesian-well prospects in the Atlantic Coastal Plain region, by N. H. Darton, 1896; octavo, 250 pp., 19 plates. Bulletin No. 138 of the United States Geological Survey; price, 20 cents.

Gives a description of the geologic conditions of the coastal region from Long Island, N. Y., to Georgia, and contains data relating to many of the deep wells.

Report of progress of the division of hydrography for the calendar year 1895, by F. H. Newell, hydrographer in charge, 1896; octavo, 350 pp. Bulletin No. 140 of the United States Geological Survey; price, 25 cents.

Contains a description of the instruments and methods employed in measuring streams and the results of hydrographic investigations in various parts of the United States.

1897.

Eighteenth Annual Report of the United States Geological Survey, 1896–97, Part IV, Hydrography, 1897; octavo, 756 pp.

Contains a "Report of progress of stream measurements for the calendar year 1896," by Arthur P. Davis, "The water resources of Indiana and Ohio," by Frank Leverett, "New developments in well boring and irrigation in South Dakota," by N. H. Darton, and "Reservoirs for irrigation," by J. D. Schuyler.

1899.

Nineteenth Annual Report of the United States Geological Survey, 1897–98, Part IV, Hydrography, 1899; octavo, 814 pp.

Contains a "Report of progress of stream measurements for the calendar year 1898," by F. H. Newell and others; "The rock waters of Ohio," by Edward Orton, and "A preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian," by N. H. Darton.

1900.

Twentieth Annual Report of the United States Geological Survey, 1898–99, Part IV, Hydrography, 1900; octavo, —— pp.

Contains a "Report of progress of stream measurements for the calendar year 1898," by F. H. Newell, and "Hydrography of Nicaragua," by A. P. Davis.

WATER-SUPPLY AND IRRIGATION PAPERS, 1896–1900.

This series of papers is designed to present in pamphlet form the results of stream measurements and of special investigations. A list of these, with other information, is given on the outside (or fourth) page of this cover.

Survey bulletins can be obtained only by prepayment of cost, as noted above. Money should be transmitted by postal money order or express order, made payable to the Director of the United States Geological Survey. Postage stamps, checks, and drafts can not be accepted. Correspondence relating to the publications of the Survey should be addressed to The Director, United States Geological Survey, Washington, D. C.

WATER-SUPPLY AND IRRIGATION PAPERS.

1. Pumping water for irrigation, by Herbert M. Wilson, 1896.
2. Irrigation near Phoenix, Arizona, by Arthur P. Davis, 1897.
3. Sewage irrigation, by George W. Rafter, 1897.
4. A reconnoissance in southeastern Washington, by Israel C. Russell, 1897.
5. Irrigation practice on the Great Plains, by E. B. Cowgill, 1897.
6. Underground waters of southwestern Kansas, by Erasmus Haworth, 1897.
7. Seepage waters of northern Utah, by Samuel Fortier, 1897.
8. Windmills for irrigation, by E. C. Murphy, 1897.
9. Irrigation near Greeley, Colorado, by David Boyd, 1897.
10. Irrigation in Mesilla Valley, New Mexico, by F. C. Barker, 1898.
11. River heights for 1896, by Arthur P. Davis, 1897.
12. Water resources of southeastern Nebraska, by Nelson Horatio Darton, 1898.
13. Irrigation systems in Texas, by William Ferguson Hutson, 1898.
14. New tests of pumps and water lifts used in irrigation, by O. P. Hood, 1898.
15. Operations at river stations, 1897, Part I, 1898.
16. Operations at river stations, 1897, Part II, 1898.
17. Irrigation near Bakersfield, California, by C. E. Grunsky, 1898.
18. Irrigation near Fresno, California, by C. E. Grunsky, 1898.
19. Irrigation near Merced, California, by C. E. Grunsky, 1899.
20. Experiments with windmills, by Thomas O. Perry, 1899.
21. Wells of northern Indiana, by Frank Leverett, 1899.
22. Sewage irrigation, Part II, by George W. Rafter, 1899.
23. Water-right problems in the Bighorn Mountains, by Elwood Mead, 1899.
24. Water resources of the State of New York, Part I, by George W. Rafter, 1899.
25. Water resources of the State of New York, Part II, by George W. Rafter, 1899.
26. Wells of southern Indiana (continuation of No. 21), by Frank Leverett, 1899.
27. Operations at river stations, 1898, Part I, 1899.
28. Operations at river stations, 1898, Part II, 1899.
29. Wells and windmills in Nebraska, by Erwin Hinckley Barbour, 1899.
30. Water resources of the Lower Peninsula of Michigan, by Alfred C. Lane, 1899.
31. Lower Michigan mineral waters, by Alfred C. Lane, 1899.
32. Water resources of Puerto Rico, by H. M. Wilson, 1900.
33. Storage of water on Gila River, Arizona, by J. B. Lippincott, 1900.

In addition to the above, there are in various stages of preparation other papers relating to the measurement of streams, the storage of water, the amount available from underground sources, the efficiency of windmills, the cost of pumping, and other details relating to the methods of utilizing the water resources of the country. Provision has been made for printing these by the following clause in the sundry civil act making appropriations for the year 1896–97:

Provided, That hereafter the reports of the Geological Survey in relation to the gaging of streams and to the methods of utilizing the water resources may be printed in octavo form, not to exceed 100 pages in length and 5,000 copies in number; 1,000 copies of which shall be for the official use of the Geological Survey, 1,500 copies shall be delivered to the Senate, and 2,500 copies shall be delivered to the House of Representatives, for distribution. [Approved June 11, 1896; Stat. L., vol. 29, p. 453.]

The maximum number of copies available for the use of the Geological Survey is 1,000. This number falls far short of the demand, so that it is impossible to supply all requests. Attempts are made to send these pamphlets to persons who have rendered assistance in their preparation through replies to schedules or who have furnished data. Requests specifying a certain paper and stating a reason for asking for it are granted whenever practicable, but it is impossible to comply with general requests, such as to have all of the series sent indiscriminately.

Application for these papers should be made either to Members of Congress or to

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C.

DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 34

GEOLOGY AND WATER RESOURCES OF A PORTION OF SOUTHEASTERN SOUTH DAKOTA.—Todd

WASHINGTON
GOVERNMENT PRINTING OFFICE
1900

IRRIGATION REPORTS.

The following list contains titles and brief descriptions of the principal reports relating to water supply and irrigation prepared by the United States Geological Survey since 1890:

1890.

First Annual Report of the United States Irrigation Survey, 1890; octavo, 123 pp.

Printed as Part II, Irrigation, of the Tenth Annual Report of the United States Geological Survey, 1888-89. Contains a statement of the origin of the Irrigation Survey, a preliminary report on the organization and prosecution of the survey of the arid lands for purposes of irrigation, and report of work done during 1890.

1891.

Second Annual Report of the United States Irrigation Survey, 1891; octavo, 335 pp.

Published as Part II, Irrigation, of the Eleventh Annual Report of the United States Geological Survey, 1889-90. Contains a description of the hydrography of the arid region and of the engineering operations carried on by the Irrigation Survey during 1890; also the statement of the Director of the Survey to the House Committee on Irrigation, and other papers, including a bibliography of irrigation literature. Illustrated by 29 plates and 4 figures.

Third Annual Report of the United States Irrigation Survey, 1891; octavo, 570 pp.

Printed as Part II of the Twelfth Annual Report of the United States Geological Survey, 1890-91. Contains "Report upon the location and survey of reservoir sites during the fiscal year ended June 30, 1891," by A. H. Thompson; "Hydrography of the arid regions," by F. H. Newell; "Irrigation in India," by Herbert M. Wilson. Illustrated by 93 plates and 100 figures.

Bulletins of the Eleventh Census of the United States upon irrigation, prepared by F. H. Newell; quarto.

No. 35, Irrigation in Arizona; No. 60, Irrigation in New Mexico; No. 85, Irrigation in Utah; No. 107, Irrigation in Wyoming; No. 153, Irrigation in Montana; No. 157, Irrigation in Idaho; No. 163, Irrigation in Nevada; No. 178, Irrigation in Oregon; No. 193, Artesian wells for irrigation; No. 198, Irrigation in Washington.

1892.

Irrigation of western United States, by F. H. Newell; extra census bulletin No. 33, September 9, 1892; quarto, 22 pp.

Contains tabulations showing the total number, average size, &c., of irrigated holdings, the total area and average size of irrigated farms in the subhumid regions, the percentage of number of farms irrigated, character of crops, value of irrigated lands, the average cost of irrigation, the investment and profits, together with a resume of the water supply and a description of irrigation by artesian wells. Illustrated by colored maps showing the location and relative extent of the irrigated areas.

1893.

Thirteenth Annual Report of the United States Geological Survey, 1891–'92, Part III, Irrigation, 1893; octavo, 486 pp.

Consists of three papers: "Water supply for irrigation," by F. H. Newell; "American irrigation engineering" and "Engineering results of the Irrigation Survey," by Herbert M. Wilson; "Construction of topographic maps and selection and survey of reservoir sites," by A. H. Thompson. Illustrated by 77 plates and 119 figures.

A geological reconnoissance in central Washington, by Israel Cook Russell, 1893; octavo, 108 pp., 15 plates. Bulletin No. 108 of the United States Geological Survey; price, 15 cents.

Contains a description of the examination of the geologic structure in and adjacent to the drainage basin of Yakima River and the great plains of the Columbia to the east of this area, with special reference to the occurrence of artesian waters.

1894.

Report on agriculture by irrigation in the western part of the United States at the Eleventh Census, 1890, by F. H. Newell, 1894; quarto, 283 pp.

Consists of a general description of the condition of irrigation in the United States, the area irrigated, cost of works, their value and profits; also describes the water supply, the value of water, of artesian wells, reservoirs, and other details; then takes up each State and Territory in order, giving a general description of the condition of agriculture by irrigation, and discusses the physical conditions and local peculiarities in each county.

Fourteenth Annual Report of the United States Geological Survey, 1892–93, in two parts; Part II, Accompanying papers, 1894; octavo, 597 pp.

Contains papers on "Potable waters of the eastern United States," by W J McGee; "Natural mineral waters of the United States," by A. C. Peale; and "Results of stream measurements," by F. H. Newell. Illustrated by maps and diagrams.

(Continued on third page of cover.)

DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 34

WASHINGTON
GOVERNMENT PRINTING OFFICE
1900

UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

GEOLOGY AND WATER RESOURCES

OF A PORTION OF

SOUTHEASTERN SOUTH DAKOTA

BY

JAMES EDWARD TODD

WASHINGTON
GOVERNMENT PRINTING OFFICE
1900

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LETTER OF TRANSMITTAL.

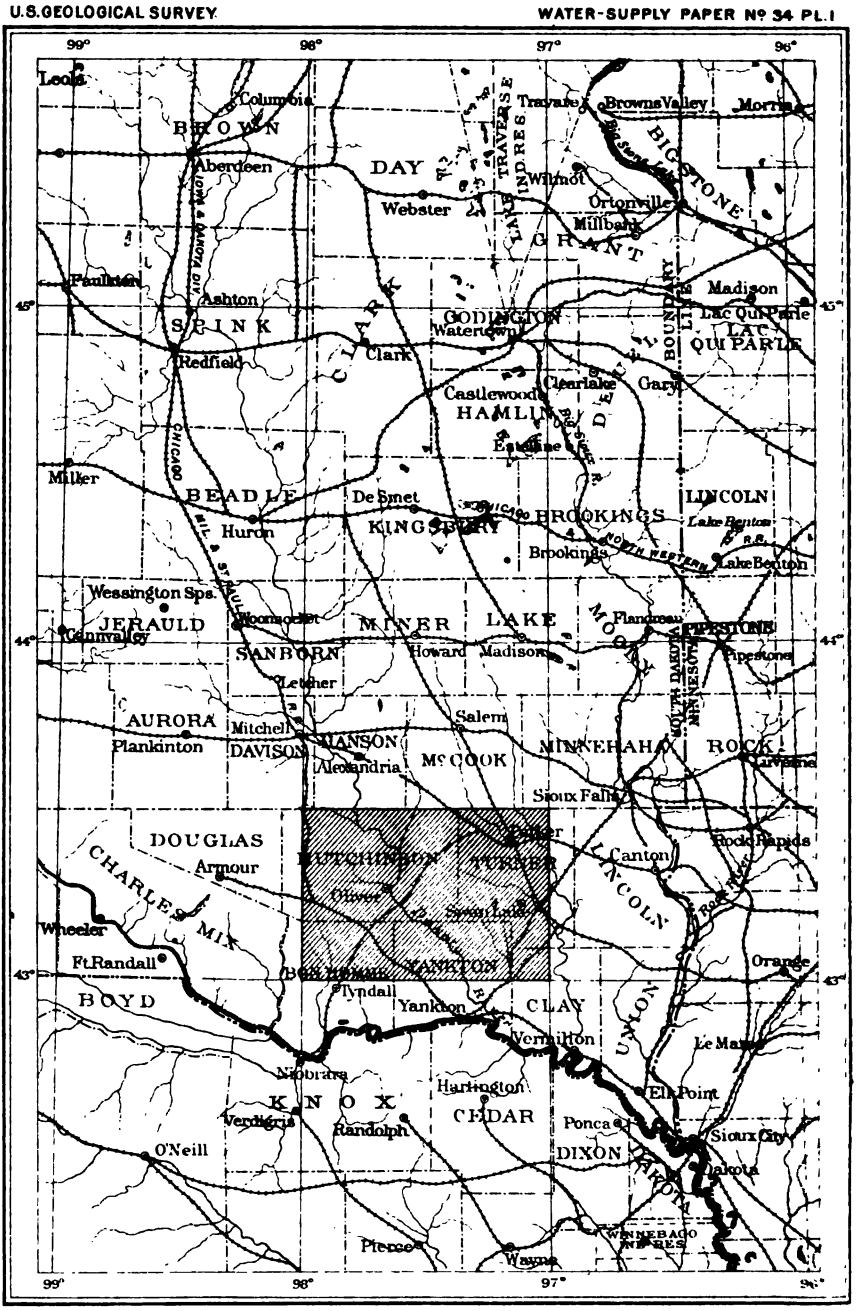
DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, February 15, 1900.

SIR: I have the honor to transmit herewith a manuscript giving the results of investigations of underground waters of a portion of southeastern South Dakota, prepared by Prof. James E. Todd, and to recommend that it be printed in the series of Water-Supply and Irrigation Papers.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.



INDEX MAP OF EASTERN SOUTH DAKOTA

Showing area under consideration

BY J. E. TODD 1899.

Scale

25 0 25 50 MILES

JULIUS BIEN & CO. N.Y.

GEOLOGY AND WATER RESOURCES OF A PORTION OF SOUTHEASTERN SOUTH DAKOTA.

By JAMES E. TODD.

LOCATION OF REGION.

The area to which this paper relates is represented on the Olivet and Parker sheets of the Topographic Atlas of the United States, published by the United States Geological Survey.[1] It occupies large portions of Turner and Hutchinson counties, and small portions of Bonhomme, Yankton, and Clay counties, South Dakota. It is especially instructive from the fact that it includes typical areas of the valleys of James and Vermilion rivers, and Turkey Ridge, which forms a portion of the divide between the two streams. Moreover, it exhibits characteristic features of two kinds of artesian supply, viz, that from the Dakota sandstone, and that from the sands underlying the drift. It also exhibits plainly the typical conditions of most forms of shallow wells, as well as the tubular wells common to the eastern portion of South Dakota. The region for the greater part is prairie and rarely so rough as to be unfavorable for ordinary agriculture. It includes wider ranges of altitude than most areas of similar extent in the Mississippi Valley; in the immediate valleys of Vermilion River, Clay Creek, and James River the surface is not over 1,180 feet above the sea, while in the northern culmination of Turkey Ridge it reaches 1,750 feet, and in the southwestern portion of the region it attains an altitude of 1,650 feet, which is considerably below the higher points of the Choteau Creek Hills a little farther west.

GENERAL GEOLOGY.

Nearly the whole surface of the area is covered with glacial drift. The exceptions are the alluvial flats in the larger valleys, and scattered exposures of older rocks occurring mainly along the sides of the canyons in the southern part of Turkey Ridge and in the bottoms of the

[1] These sheets may be procured at 5 cents each by addressing The Director, United States Geological Survey, Washington, D. C.

river channels. The strata lie nearly horizontal everywhere. No folds, faults, or igneous outflows have been discovered. Frequent borings have been made to a depth of 200 or 300 feet in obtaining wells, and a few have been sunk to 600 or 700 feet. These have furnished important facts concerning the position of strata below the surface.

ALGONKIAN.

SIOUX QUARTZITE.

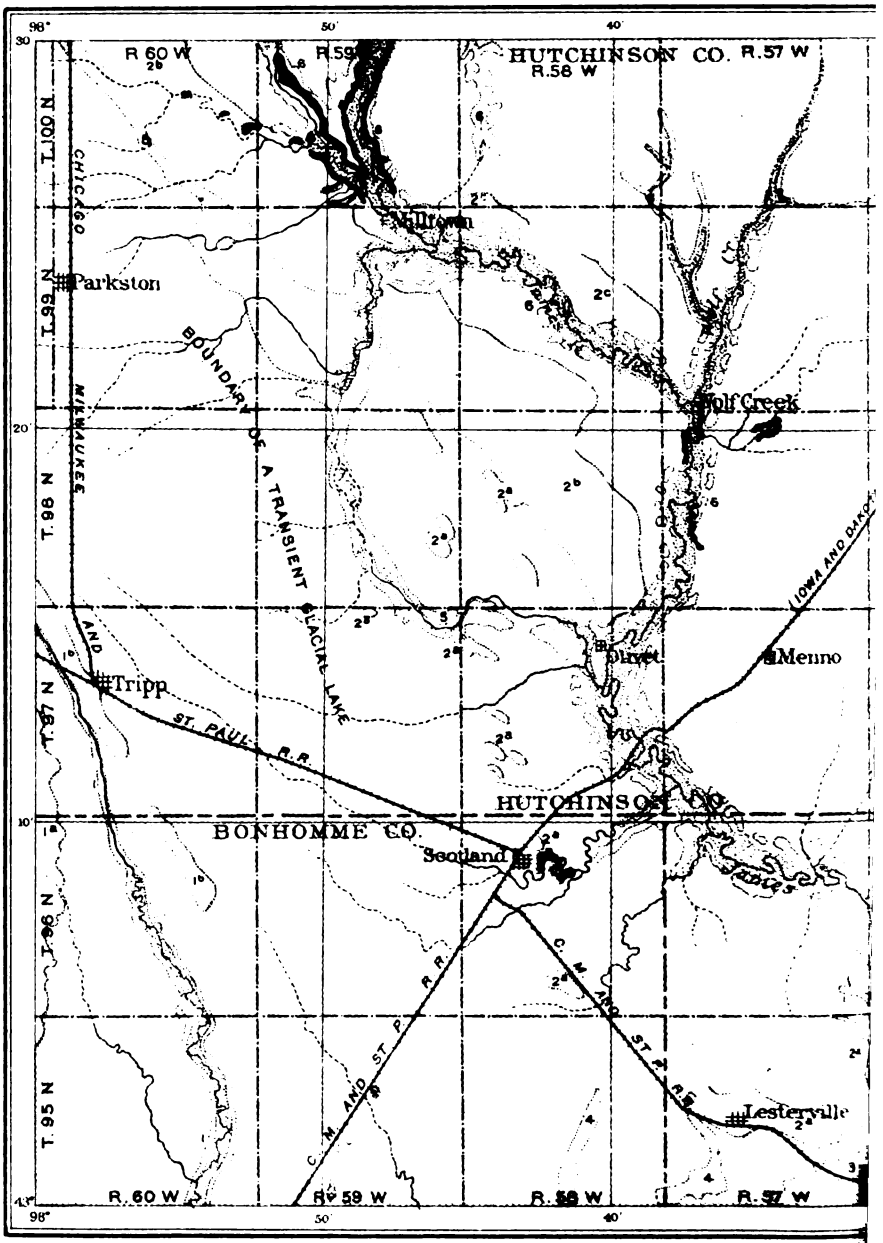
The oldest rock exposed in natural outcrops or by borings is the Sioux quartzite, a name given by Dr. C. A. White, when State geologist of Iowa. Exposures are found at a number of points along the East Fork of Vermilion River from the north line of Turner County to the vicinity of Parker, their location being indicated on Pl. III. Borings some distance from these exposures have shown that this formation is "bed rock," and the depth to its surface is indicated upon the map (Pl. IV). The rock is frequently called Sioux Falls "granite," from the extensive exposures and numerous quarries in the vicinity of Sioux Falls. It is for the most part a red or purplish quartzite of intensely compact and durable character, and is susceptible of a fine polish. It lies in strata which dip generally to the north at an angle of 3° to 5°. In sec. 8, T. 100 N., R. 53 W., it is in layers which are generally not more than 6 inches in thickness. East of Parker it is more massive, and the layers are 2 or 3 feet in thickness. No trace of slate or pipestone has been found in any of these exposures. No fossils have been noted in the formation anywhere, except some small lingulæ found by Prof. N. H. Winchell near Pipestone, Minnesota.[1] This formation is generally referred to the Algonkian. Its thickness has not been determined. At Sioux Falls a boring 500 feet deep revealed no important difference in the character of the rock.

THE PALEOZOIC GAP.

In this region there are no traces of Paleozoic formations nor of the Triassic and Jurassic of Mesozoic time. The surface of the Sioux quartzite shows marks of long erosion at an elevation of several hundred feet above sea level. The nearest occurrence of Paleozoic rock that has been discovered is in the borings at Ponca, Nebraska, and Sioux City, Iowa. While the mountain masses of the Appalachian region and the extensive coal fields of the eastern part of the Mississippi Valley were forming this area was probably a barren mountainous region. It is possible that soils and vegetations which may have extended over it were removed by the advance of the sea during Cretaceous time. At any rate, no traces of soil are now found upon

[1] Sixteenth Ann. Rept. Geol. Nat. Hist. Survey Minnesota.

U.S. GEOLOGICAL SURVEY



GEOLOGICAL MAP OF A PORT

BY J.E

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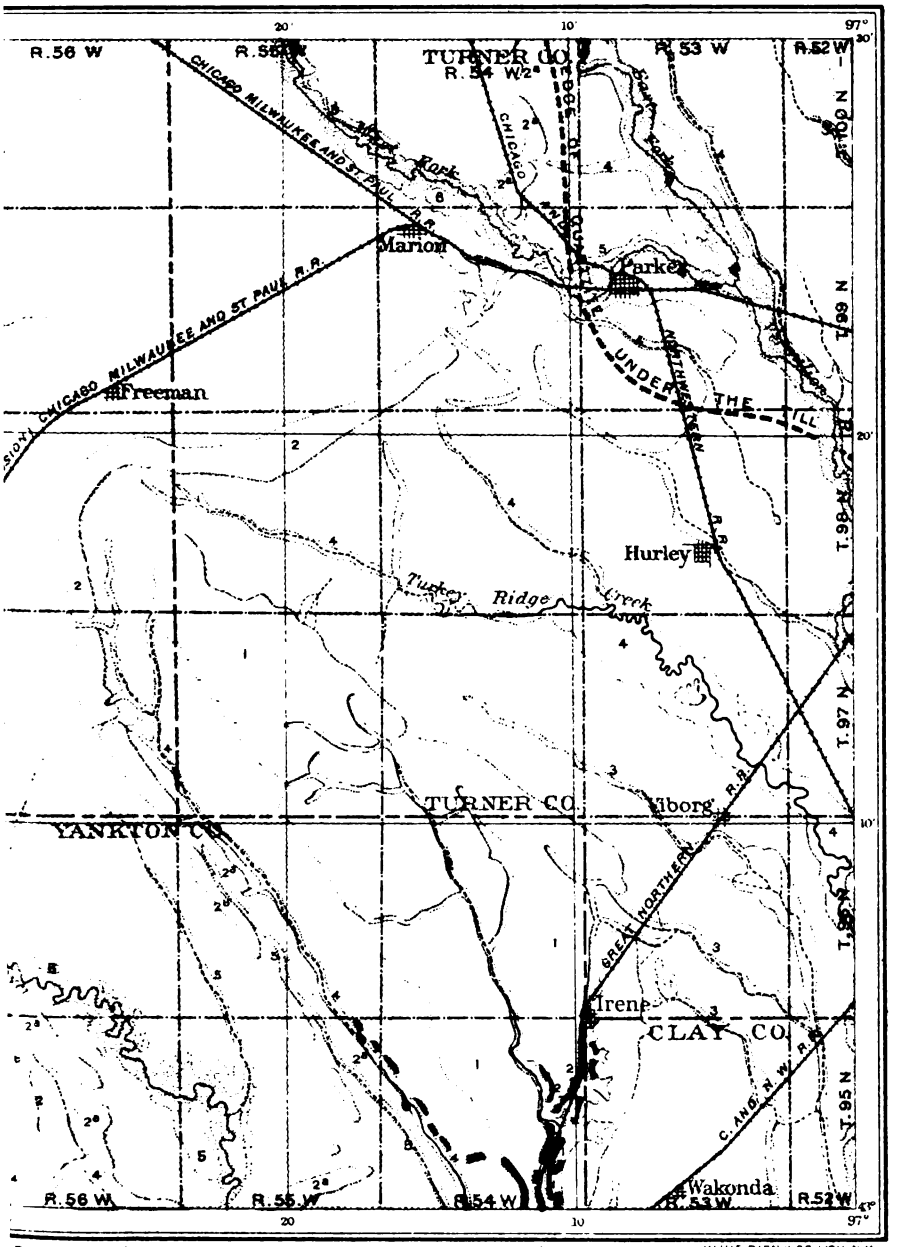
ALGONKIAN

SIOUX QUARTZITE

CRETACEOUS

DAKOTA FORMATION

COLORADO FORMATION



N OF EASTERN SOUTH DAKOTA

DD 1899

JULIUS BIEN & CO. LITH. N.Y.

10 15 MILES

ND

PLEISTOCENE

	TILL	ANCIENT CHANNELS (Numbered in order of occupation)	ALLUVIUM

GS
lin order
tion.

the surface of the quartzite. Since several hundred feet of strata of marine origin, representing all the ages of Paleozoic time, are found in the Black Hills, the shore of the Paleozoic sea must have extended across South Dakota somewhere west of the present course of the Missouri River. Moreover, as the Triassic formations of the Black Hills testify to an inclosed sea, barren of life, we must believe that during that epoch this inland sea was detached from the ocean.

CRETACEOUS.

Resting upon the Sioux quartzite, as revealed by borings, there are sands, chalk, and clays belonging to the Cretaceous. We have no trace of the earlier beds which represent this age elsewhere, but several hundred feet of the later Cretaceous deposits underlie much of the area.

DAKOTA SANDSTONE.

Resting upon the quartzite, as shown by many borings, there is a series of sandstone and shale which Dr. F. V. Hayden, the first United States geologist who examined this region, named the Dakota formation, from extensive outcrops near the town of Dakota, in Nebraska. This formation is only exposed in this area along James River and Twelvemile Creek above Milltown, and about the junction of Wolf Creek and James River. Its general distribution underground is, however, well shown by the borings of the deeper artesian wells. From these data the formation is known to underlie the area, except in the region about Parker and northeastward. As the surface of the quartzite is uneven and the upper portion of the Dakota sandstone is more or less eroded, the margin is quite ragged and uneven. In the southern part of the area, the Dakota deposits probably have a thickness of 300 or 400 feet, but as deep borings in that region are few, and none are known to have penetrated to bed rock, this is only an estimate. From borings in this area and from exposures elsewhere, it is known that the formation is composed of sheets of sand or sandstone more or less completely separated by thick beds of clay and shale. The sandstone strata are usually of fine-grained, well-washed materials, and vary in thickness from 10 to 100 feet. The clay deposits are in general thick, and very often form a hard shale; locally they include compact limestone, plastic clay, and iron pyrites. The last is very hard and forms a serious obstacle in drilling. The number of sand strata which are water bearing increases toward the south, where the formation thickens.

In eastern South Dakota the upper part of the sandstone is a stratum generally presenting harder layers often spoken of as "cap rock." They are sometimes so hard as to give the impression that the red

quartzite has been struck, but in all cases, so far as known, the cement is calcareous or ferruginous rather than siliceous, as in the quartzite. Its calcareous character is revealed by use of an acid, which causes effervescence; the ferruginous cement is shown by its dark color.

The Dakota sandstone underlies all the area except a small district near Parker. It is exposed extensively along the James River and Twelvemile Creek above Milltown, and also near the mouth of Wolf Creek. At the latter place it seems to be in a low arch or anticline lifted to a height of 25 or 30 feet above the level of the James River. The principal exposures are upon the west side of the river, in sec. 6, T. 98 N., R. 57 W. The material here is a soft, irregularly stratified sandstone scarcely hard enough for building purposes. Exposures on the James River above Milltown begin about a mile above that point in the form of low barren slopes on both sides of the river, which gradually rise until south of Elmspring the upper portion of the formation is about 60 feet above the level of the James River. Here it exhibits a few castellated cliffs. About 1½ miles south of Elmspring, upon the east side of the valley, the following section is exposd:

Section 1½ miles south of Elmspring, South Dakota.

	Feet.
Slope of till	50
Soft brown sandstone, some pebbles above; irregularly stratified, springs below	35
Slope mostly clay, evidently Dakota, to the level of the James River	20

Farther south, about a mile above Milltown, the sandstone is more perfectly consolidated and shows much oblique lamination, and it has been quarried to some extent for building purposes. The sandstone appears on both sides of Twelvemile Creek, following the main stream for 3 or 4 miles. North of the northeast corner of sec. 34, T. 100 N., R. 59 W., it has been quarried considerably. The following section of a well near Elmspring exhibits this formation more completely:

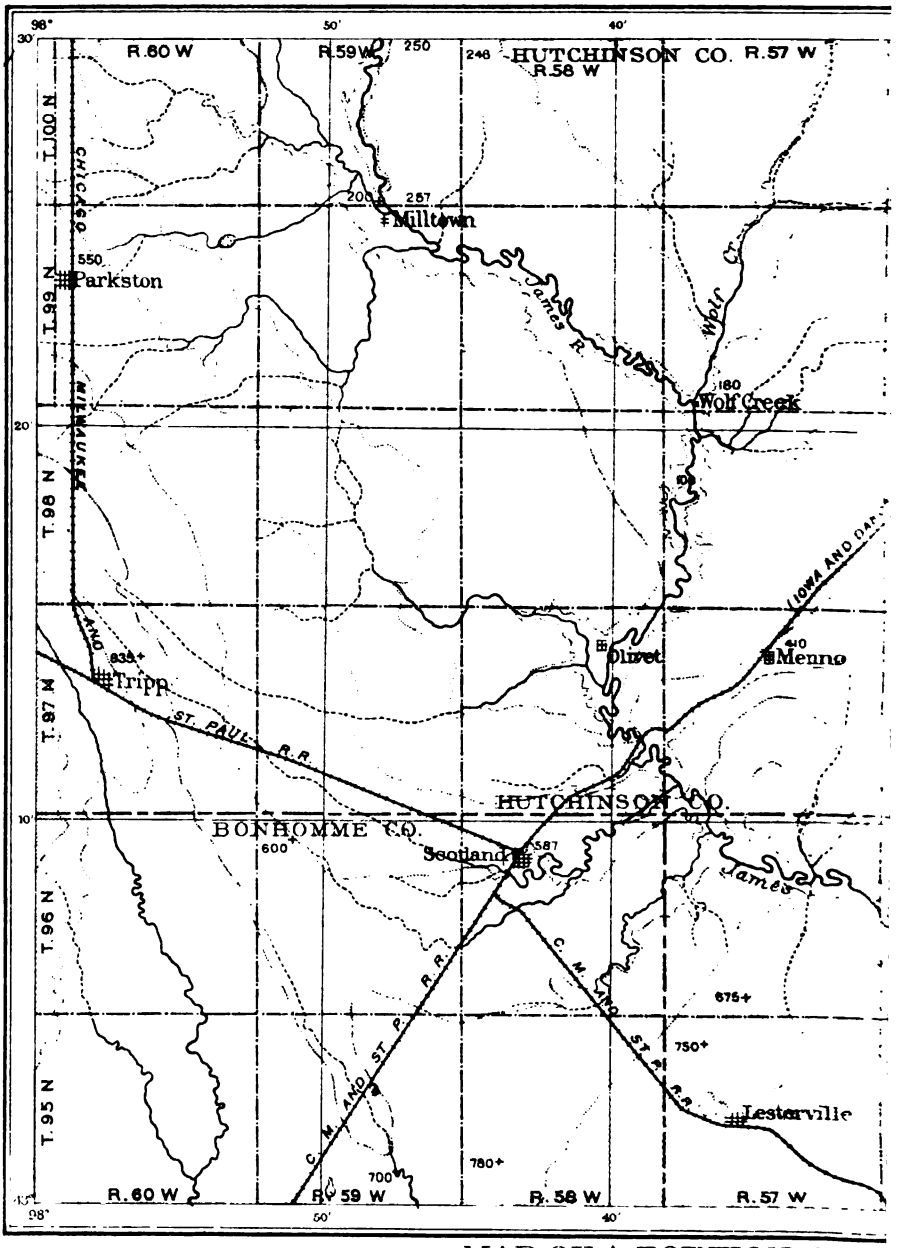
Section in well at Elmspring, South Dakota.

	Feet.
(1) Yellow and blue clay (till) with water at 60 feet	83
(2) Sandstone	8
(3) Sand	20
(4) Sandstone and clay, irregularly stratified	20
(5) "Blue clay" (shale), with one or two strata of sandstone	116
(6) Red quartzite	70

All except No. 1 and No. 6 belong to the Dakota formation.

The formation thickens by the intercalation of other strata, both toward the west and south. Near the James River, at the southern portion of the area, wells indicate that the Dakota formation may be from 300 to 400 feet in thickness. A characteristic view of the upper portion of the formation, as shown on the Firesteel northwest of Mitchell, is given on Pl. IX, *A*.

U.S.GEOLOGICAL SURVEY



Note. Figures denote depths of borings
If without + sign quartzite was met with at that depth
All depth areas estimated averages
The quartzite surface has many local irregularities

MAP OF A PORTION OF E

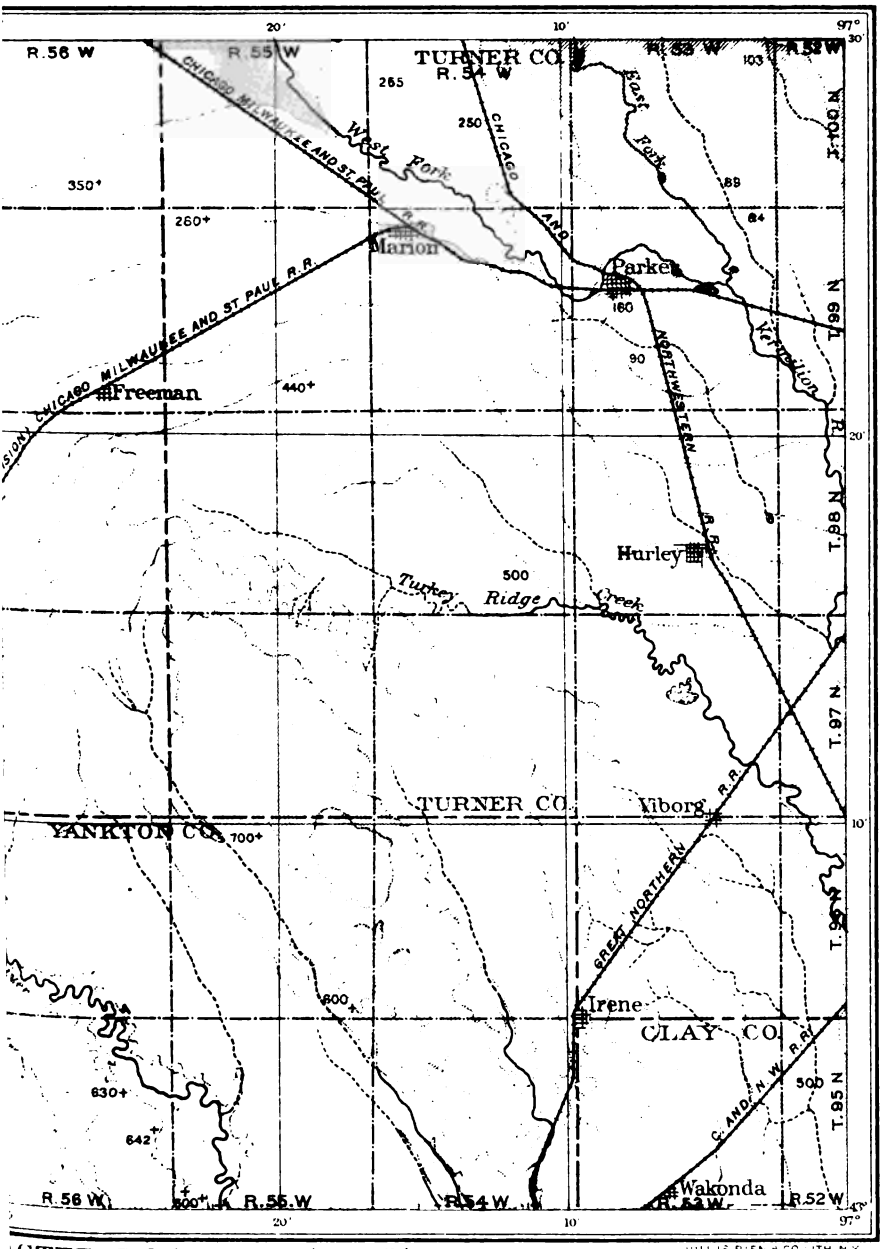
Showing dept

BY J. E.

S

5 0

0 | 0 - 100' | 100 - 200 | 200 - 300' | 300 - 400 | 400 - 5



JULIUS BIEN & CO. LITH. N.Y.

ASTERN SOUTH DAKOTA

s to bed rock

D. 1899

le

10 15 MILES

500'-600' 600'-700' 700'-800' 800'-900' 900'-1000' 1000'-1100'

COLORADO FORMATION.

This includes two series of deposits, which were first separated by Dr. F. V. Hayden. The lower series, composed mostly of shale and clay, was named Benton, from its great development near Fort Benton, Montana, and the upper series, composed largely of chalkstone, was called Niobrara. These two subdivisions, though usually differing considerably in lithologic character, are often grouped together because of the similarity of the fossils which appear in them. Moreover, the line between them is not easily established, because in many places the chalk grades into the clay and shale; and even when fairly pure, enough protoxide of iron is present to give it a bluish tint resembling the shale. It has been found very difficult to separate them in this area by means of the reports of well-borers. One well-borer will say that within a given region he has struck no chalk, but has struck shale and clay. Another will distinguish between the chalk and the clay, recognizing the fact that the former differs from blue shale or "soapstone," while a third may speak of the chalk as a fine sand. Practically, the distinction which is most obvious to the well-borer is that chalk does not become plastic by becoming wet, but acts more like fine sand. On the other hand, the shale, or "soapstone," as it is frequently called, becomes plastic and sticky, and not easily distinguished from the clay except by its hardness.

The Colorado formation is exposed in this region only at a few localities, which are indicated upon the map, viz: Along the South Fork of Twelvemile Creek; on Wolf Creek, about 6 miles above its mouth; 2 or 3 miles south and east of the latter point, and still more prominently in the vicinity of Scotland. It also appears conspicuously along Turkey Creek between Irene and Volin, and also along Clay Creek north of the latter place. From a study of the formations along the Missouri River it is inferred that the Niobrara chalkstone is quite evenly stratified, compact, with some of its layers forming a hard limestone, but more frequently the clayey material is more prominent. From the exposures along the river it would seem that it has a thickness of 150 to 200 feet. Its original thickness was probably not uniform, but it was accumulated in large lenticular masses.

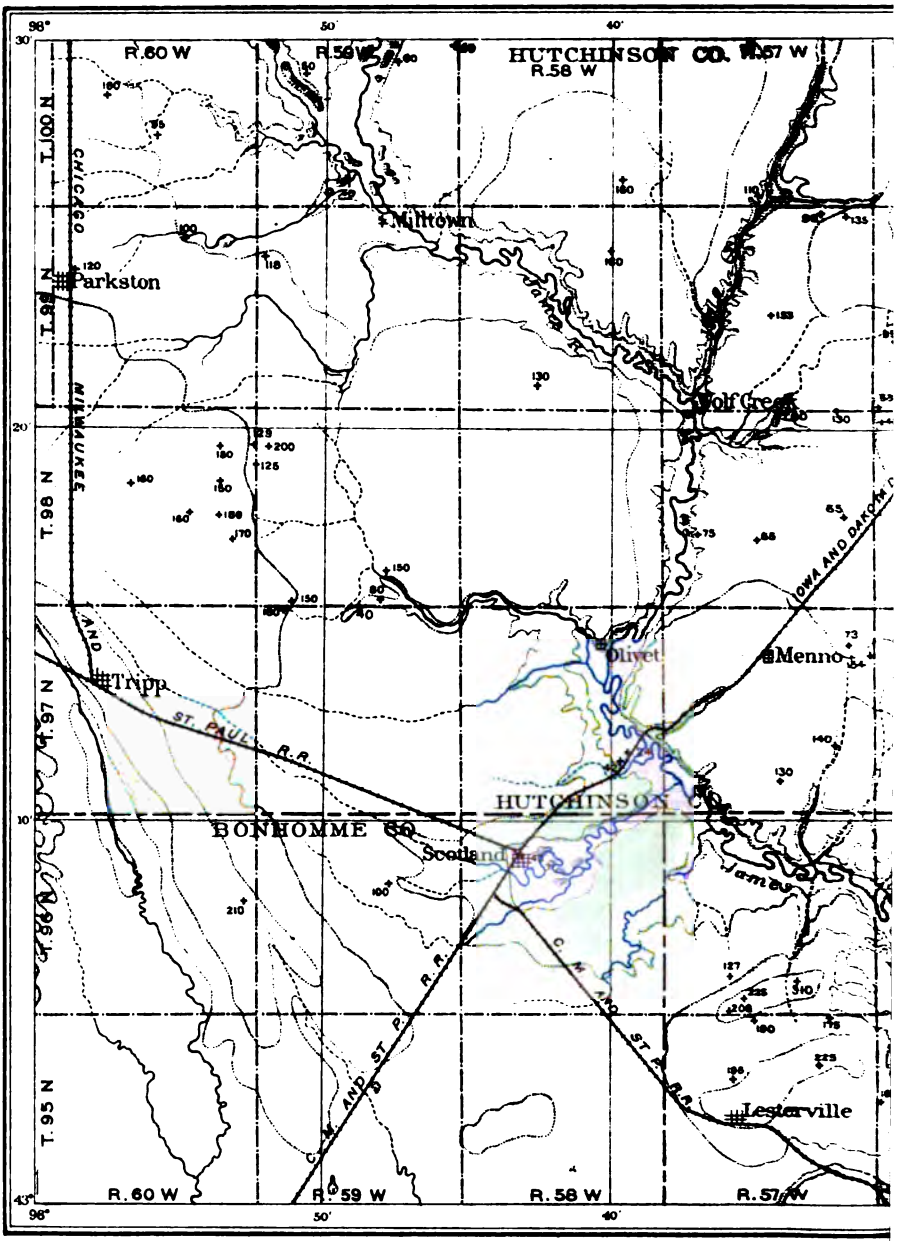
At Scotland and near Milltown the stone has been quarried and used for building. When first taken out it is easily cut with a knife and shaped to any form desired. When thoroughly seasoned it resists the weather so that buildings formed of it have stood for twenty-five or thirty years. When exposed upon a slope it crumbles under the action of frost and becomes a white earthy mass. The protoxide of iron, which colors it blue or light gray when exposed to the weather, becomes a yellow oxide or a carbonate, so that where it is near the surface the chalk soon becomes a light yellow or pure white color. It contains

fossils that characterize it elsewhere in the Missouri River Valley, including *Ostrea congesta*, different species of *Inoceramus*, some of them of large size, but usually much broken; a large shell apparently a *Pinna*, and numerous scales and teeth of fishes, both of sharks and common bony fishes. Elsewhere the bones of large reptiles have been found in this formation, but as yet none have been found in it in this area. The chalk rarely shows noticeable shells of Foraminifera, but the mass of the deposit is found by microscopic examination to be composed of coccoliths and other minute organisms found in the chalk elsewhere. At some points the chalk is found to pass laterally into a light-gray clay, and it would seem that chalk and clay might have been formed contemporaneously in neighboring parts of the sea bottom. The difficulty of determining the real thickness of the chalk in this region arises from the fact that well-borers do not readily distinguish between it and the overlying and underlying clays and shales. In no case has it been reported thicker than 100 feet except at Tripp, where it is stated to be nearly 300 feet thick. It is probable that it varies greatly in different localities, though in general it appears to thicken toward the southwest, like the other formations which we have considered. It has not been so much removed by erosion in that direction.

The Benton shale is not clearly exposed at any point in this area. From the study of it along the Missouri River it is found usually to be composed of a dark clay, easily absorbing water and quickly becoming very plastic. At a locality southwest of Mitchell it is excavated for making brick, and one quite striking feature is that the sides of the pit are constantly sliding in, and even in the adjoining prairie the slope is marked with crevasses or cracks, indicating its creeping nature. Similar features have been noted in sec. 33, T. 100 N., R. 59 W., on a slope above the Dakota sandstone and below the level of the chalkstone. It is impossible to estimate the thickness of the formation with any accuracy, but there is clear evidence that the clayey member corresponding to the Benton is found here in considerable quantity. It is probably 50 feet thick. Elsewhere it has been reported in borings as underlying the chalkstone and lying on the sandstones of the Dakota.

Before the deposition of the Colorado formation the Dakota sandstone seems to have been somewhat eroded, especially in the highest portions adjoining the quartzite. Possibly this was due to "contemporaneous erosion" rather than to true unconformity; that is, it was due to the action of tidal currents or waves cutting out channels without any exposure to the action of streams upon a land surface. Moreover, the Colorado overlaps considerably beyond the edge of the Dakota sandstone.

U.S.GEOLOGICAL SURVEY



+ 210 (etc.)
Representative wells and their depth in feet which obtain pump water at base of till

MAP OF A PORTION OF E

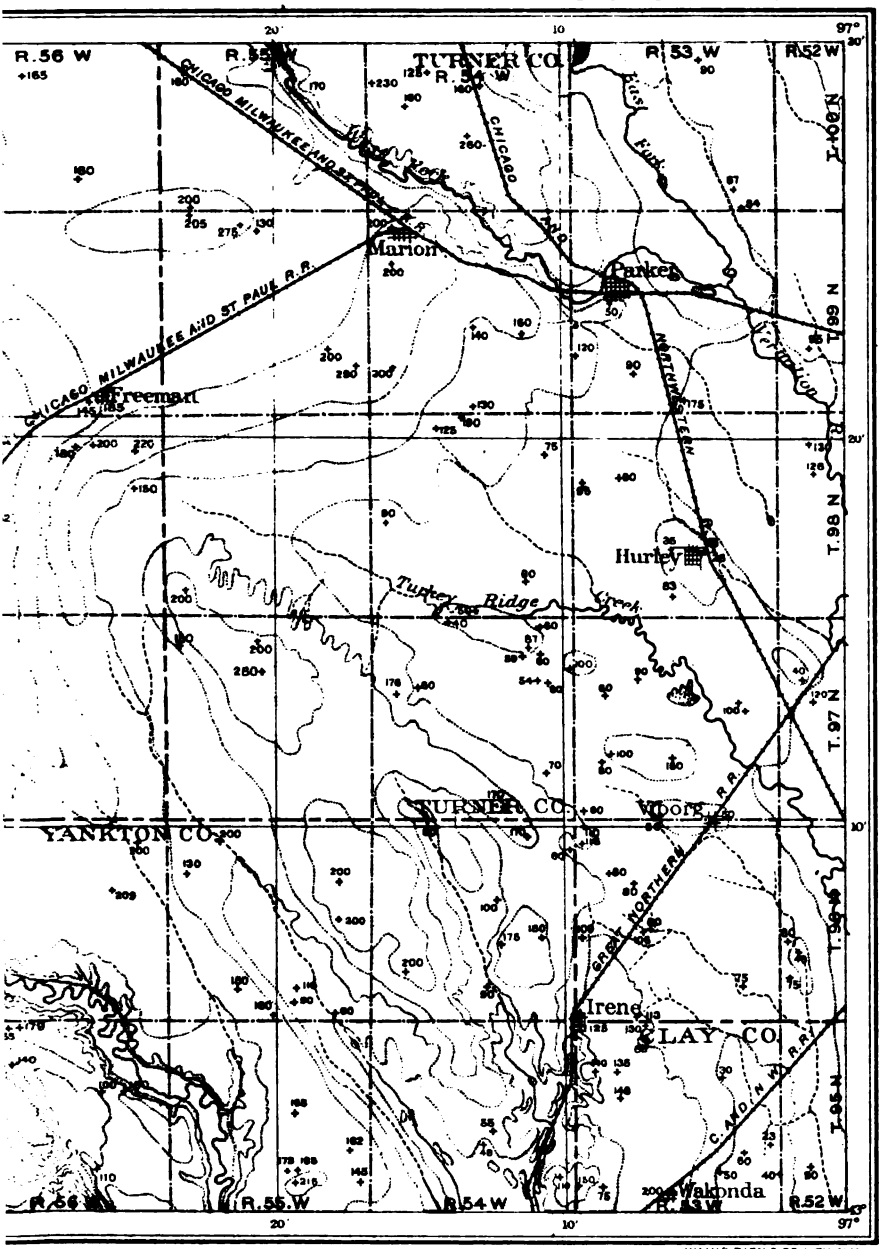
Showing depths to wa

BY J.E.

Sc

5 0

0' | 0'-50' | 50'-100' | 100'-150'



JULIUS BIEN & CO. 11TH N.Y.

STERN SOUTH DAKOTA

rs at base of the till
) 1899

10 15 MILES

150'-200' 200'-250' 250'-300' 300'-350'

PIERRE SHALE.

Pierre shale follows next in succession to the Colorado formation, and is very thickly developed along the Missouri River above the Niobrara chalk. It undoubtedly overlies that formation also in the Choteau Creek Hills, though it has not been distinctly recognized there in exposures or in wells. Upon Turkey Creek, on the east side of sec. 11, T. 95 N., R. 54 W., a few feet of dark, plastic clay overlies the chalkstone, which doubtless is Pierre. Careful examination will probably reveal other similar exposures. It is a formation which often contains remains of marine reptiles and many cephalopod shells. The shales are quite calcareous and their fossils are frequently embedded in large concretions of limestone.

TERTIARY DEPOSITS.

The only natural exposures in the area under consideration which may possibly belong to the Tertiary are beds of a yellow loam resembling loess, which occur overlying the Cretaceous at several points on Turkey Creek, also southeast of the mouth of Wolf Creek. These are underneath the glacial drift and may possibly belong to the Pliocene. Borings in the higher portions of Turkey Ridge and the Choteau Creek Hills reveal thick deposits of sand underneath the till. These also may belong to the Tertiary, and may be even as old as the Loup Fork. On the other hand, it is possible that they are accumulations preceding the deposition of the drift during the Pleistocene. No fossils have been discovered, so no conclusion can be confidently expressed as to their age.

PLEISTOCENE DEPOSITS.

In this region the Pleistocene deposits are very prominent and cover very nearly the entire surface. All the exposures of older rock do not occupy more than 4 or 5 square miles. The deposits of this epoch may be enumerated in chronological order, as follows: (1) The preglacial or circumglacial sands and gravels; (2) the glacial till or bowlder clay, separable into the upper or yellow bowlder clay and the lower or blue bowlder clay; (3) the moraines, which include those of two distinct epochs, with minor subdivisions; (4) terraces and ancient channels, which may be referred to three or four different stages of the glacial occupation of the country; (5) alluvium.

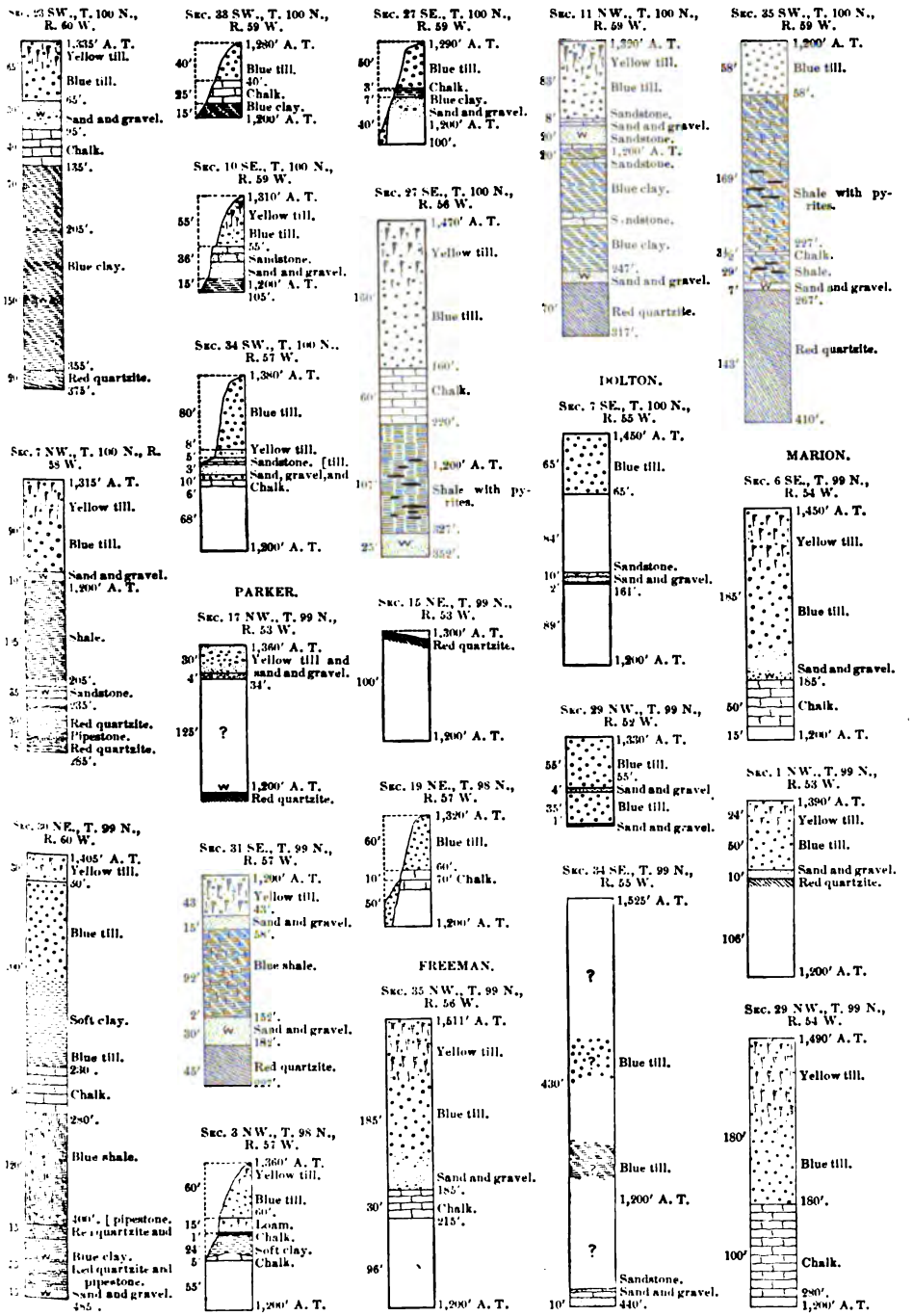
PREGLACIAL OR CIRCUMGLACIAL DEPOSITS.

The preglacial surface was probably covered with silt and clays resembling those of the region now found west of the Missouri. The surface there, however, is probably now eroding faster than at that time, for the base-level of drainage was probably much higher relatively

and of gentler grade. The hillside wash and alluvium was perhaps more marked than is now found in the trans-Missouri region, but as the ice sheet, which resembled that of Greenland at the present time, slowly advanced from the north there was spread before it almost everywhere a fringe or apron of torrential deposits. Heavy sand and gravel bars accumulated along the channels of the principal streams leading from the ice sheet. A less amount of similar deposit was accumulated in all water courses as their upper portions began to be supplied from the melting ice. Hence, most of the surface became covered with a nearly continuous but uneven layer of sand and gravel, and as the result of the process we find to-day nearly everywhere below the till, or blue clay, of this region a stratum of sand and gravel, containing in most cases abundant water. The finer portions of preglacial soil and surficial deposits of that time seem to have been washed away, leaving the sand clean and porous. This deposit of sand, which may be compared to a blanket, lies over the uneven surface of the Cretaceous clays, mantling the upland as well as the lowland. It appears to be generally thicker upon the higher points, where its accumulation may have been due in part to the action of winds. It is needless, perhaps, to remark that the sands of this deposit, like the bowlder clay above, contain pebbles of granite, greenstone, and limestone. This deposit is rarely exposed, but there are a few places along the base of the bluffs of the James River where it appears. The more notable ones are about a mile below Milltown, and at intervals for 2 or 3 miles above the mouth of Wolf Creek. It may be recognized at other points by the appearance of springs near the level of the stratum. It appears, usually with less thickness, above the older rocks wherever they are exposed. There, however, it is less frequently the source of springs, because such points are more elevated, and because the bowlder clay has crept down and covered it more often than where it has been more recently exposed by the action of the streams. Sometimes this deposit attains a thickness of 100 feet, but generally it is very much thinner. In some cases it may be entirely wanting, so that the well-borer passes from the bowlder clay into the Cretaceous beds without noticing the transition. This formation plays an important part in the water supply of the region and will be further described under that head.

TILL OR BOWLDER CLAY.

This formation presents the same features that are found in corresponding regions elsewhere, as in central Minnesota, Iowa, and Illinois. It is an unstratified mixture of clay, sand, and worn pebbles and bowlders, the last mentioned sometimes attaining a diameter of several feet. In this formation are found local developments of stratified sand, commonly spoken of as pockets, though they are



LOGS OF WELLS IN HUTCHINSON COUNTY, SOUTH DAKOTA.

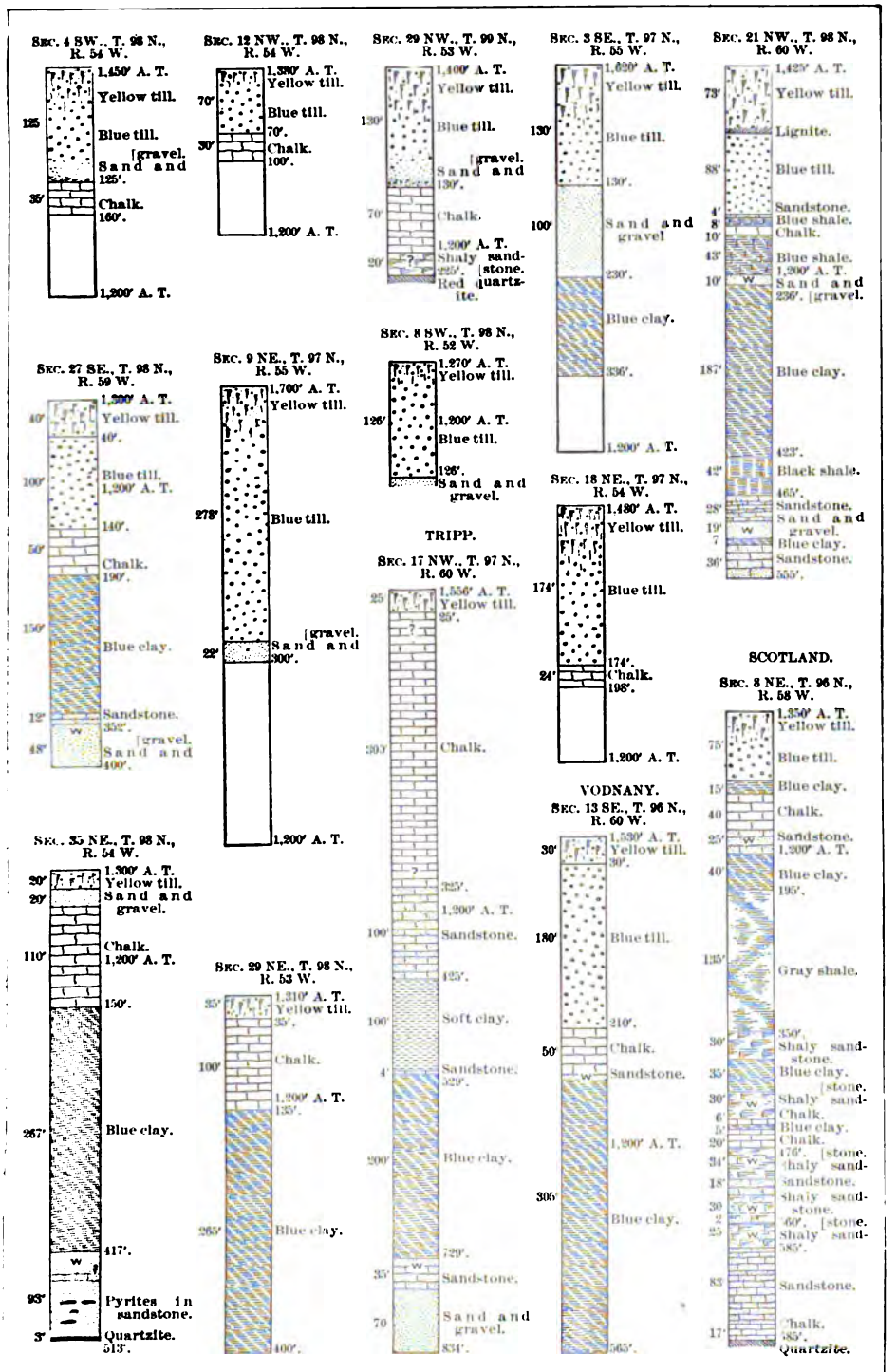
sometimes known to be portions of channels of considerable length, and also of sheets that may locally separate the bowlder clay into two or more members. The till of this region is much more clayey than at points farther east because for some distance the ice had moved over and deeply eroded the dark-colored clays of the Cretaceous. For this reason the erratics are perhaps less frequently striated and planed. The bowlders most widely distributed are gray and reddish granites, and peculiarly compact and fine-grained limestones of a straw color or clear white. The latter contain *Favosites* and cup-corals, with occasional Brachiopods, indicating their Paleozoic origin. Next in prominence are bowlders of a fine-grained trap or greenstone. Besides these, in some portions of the area, a large percentage of the erratics, usually those of smaller size, came from a red quartzite ridge lying to the north. The distribution of these is so remarkable about Turkey Ridge as to attract popular attention. In the main part of this ridge they form about 90 per cent of all bowlders, but outside of or across the valleys of Clay and Turkey Ridge creeks they are very rare. The till varies in thickness from 80 to 250 feet. In general it is thickest upon the higher elevations—as, for example, the Choteau Creek Hills and James Ridge. Near the exposures of the older rocks, which we may suppose to represent points that have resisted preglacial erosion so that they are relatively more elevated, a thickness of less than 50 feet is found, as in the vicinity of Scotland and Elmspring, but over the even surface between Parkston and Olivet it amounts to 125 or 150 feet. Between the Choteau Creek Hills and James Ridge the thickness is frequently 300 feet. It is probable that the thickness is not very uniform and may vary greatly within short intervals. Apparently the surest evidence of reaching the bottom of the till is that the water when struck rises promptly and to a considerable height. This is a fact which well-borers remember and recognize more distinctly than any discrimination of material, for pebbles and bowlders are found in both the till and the sand below. It is not uncommon for two neighbors to sink wells, one having to go to a depth of 250 or 300 feet, while the other may obtain water within 150 or 200 feet. This evidence is not always decisive, for there are sometimes within the till local developments of sand which yield abundant water. However, in many cases the wells have gone farther and demonstrated that in such cases, no till is found below the sand.

It has been noted in other regions that the till consists of two or more numbers belonging to different epochs, and it would seem not improbable that such occurrences may be discovered in this area, but thus far we have been unable to ascertain that this is the case. This is the more remarkable when we consider the number of borings which have extended not only through the till, but to the Dakota sandstone

below. However, since well-borers are not discriminating in this matter, more careful observations may eventually reveal the fact that such a division of the till really exists, at least in the vicinity of moraines. We may mention in this connection a singular phenomenon which occurs about 6 miles east of Wolf Creek colony. In the extreme northeastern corner of T. 98 N., R. 57 W., and in the sections adjoining, are three or four flowing wells obtaining water from a depth of from 55 to 65 feet, while 1½ miles farther west no water is obtained until a depth of about 150 feet is reached, and then it has not sufficient head to flow. This would suggest a division of the till into two members, separated by a sand deposit which does not extend to the second locality mentioned above. This may prove to be a separation of the earlier and older deposit of till, and may extend farther east, and may be caused by the recession and readvance of the ice, corresponding to the interval between the Altamont and Gary moraines. Another explanation may be equally satisfactory, viz, that at one time there existed in the region of flowing wells a subglacial channel which deposited a sheet of sand, which would be strictly subglacial, upon the formation of till already laid down by the glaciers while the till above was of englacial origin and was deposited above the sand deposits of said stream during the final melting of the ice sheet. Similar suppositions may explain similar flowing wells both north and south of the area named and also east of Parkston.

As elsewhere, the upper part of the till has, when weathered, a light buff or yellowish color. This is so prevalent that it is only at unusually recent natural exposures, or in the digging of deep wells, that the blue character of the unweathered till appears. An impression prevails that it differs materially in character from the yellow till, since the yellow till contains water, often in considerable quantity, which supplies the shallow or surface wells of the country. It is a general rule that if sufficient water is not struck before the blue clay is reached, no more can be expected until that formation is completely penetrated. The blue clay is frequently spoken of as joint clay, from the fact that it is usually divided into polygonal masses by irregular joints crossing one another. These allow slight motion whenever the formation lies upon a slope, so that in the vicinity of streams, though less plastic than the Cretaceous clays, it is subject to landslides, which cause it to cover the underlying sands.

The surface of the till, as elsewhere, abounds more or less in shallow basins or lake beds, which may be filled with water in the wet season. In some localities these are so deep that they retain water several feet in depth year after year, but more frequently they are dried up by the advancing summer and are capable of tillage. Since none of them are supplied except by rainfall, even the deepest are apt to become empty after a succession of dry years.



LOGS OF WELLS IN HUTCHINSON COUNTY AND IN NORTHEASTERN PORTION OF BONHOMME COUNTY, SOUTH DAKOTA.

MORAINES.

These are local developments of the till in the form of elevated ridges, usually with the surface rougher than elsewhere. In other words, the surface rises into abrupt ridges or knolls perhaps to the height of 25 or 30 feet, though we do not find the best examples of such topography in this area. The intervening depressions and basins are also more numerous than elsewhere. Moreover, the moraines usually present a larger number of bowlders and beds of gravel, and bear other marks of abundant and free-flowing water. They are generally looked upon as marking the line where the edge of the ice sheet remained stationary for a considerable length of time. While the ice gradually brought materials to that point, the process of melting prevented its farther advance, and as the ice melted the clay and gravel contained in it were dropped along its edge. With this explanation we can easily understand how some areas would be much more abundantly supplied with materials than others, because of differences in velocity and load of the ice and in its relation to the attending waters. We rarely find the edge of the ice sheet clearly marked for any great distance by morainal deposits. The moraines are usually best developed at higher levels. Where the edge of the ice sheet rested in still water, whether in a lake or a sluggish stream, the material brought up by the ice would be widely distributed by the water and a comparatively level surface would be formed. Where the edge of the ice was washed by the stream for some distance, the material contributed by the ice would be carried away and hence not deposited as an accumulation.

In the area under consideration we have portions of two systems of moraines, with minor subdivisions. These are believed to belong to the Wisconsin stage of the Glacial epoch, and are known as the first, or Altamont moraine, and the second, or Gary moraine. The first moraine includes the hills in the northeastern corner of the Parker quadrangle, and the main portions of Turkey Ridge and James Ridge, and the whole of the Choteau Creek Hills. The surface in all these areas is more elevated than the region within the moraine, and is usually marked with stony hills, with more numerous and deeper basins between.

The second, or Gary moraine, is represented by the ridge beginning east of the West Fork of the Vermilion and forming the divide between it and the East Fork of the Vermilion. It passes south and southeast around the head of Turkey Ridge, then south along the east side of the same to the southern line of the area, where it turns west and skirts the eastern slope and around the northern end of James Ridge; thence, for several miles, it is imperfectly represented by the ridges near Lesterville and the gravelly hills at Scotland. These seem to mark the earlier stage of its deposition. North of Olivet it again appears

more continuous, but of subdued form, and extends northwest along the divide south of Twelvemile Creek to the northwest corner of the area. In general, this moraine is of lower elevation than the first, and has its knolls less prominent. Its highest portion is southeast of Freeman, where it attains an altitude of more than 1,600 feet.

ANCIENT DRAINAGE SYSTEMS.

Connected with these moraines are ancient systems of drainage, quite distinct at several points from those of the present time. We will not dwell upon them further than to call attention to some of the more notable cases. During the occupation of the first moraine the drainage from between the lobes of ice occupying the Vermilion Valley and the James was by means of Turkey Creek and its branches. Similarly, upon James Ridge, between the James River lobe of ice and the one to the west, are imperfect traces of a similar system. During the occupation of the second moraine the drainage was largely down the present course of the West Fork of the Vermilion River, Turkey Ridge Creek, Clay Creek, and Beaver Creek, and at that time a lake of considerable extent occupied the Vermilion Valley, east of Hurley. A much more transient one also occupied the region west of the ice sheet northwest of Scotland, which, for a time, drained toward the south into the upper part of Beaver Creek, but soon found its outlet down the James River Valley. The latter stage of this lake seems to have persisted along the valley of Dry Creek, east of Parkston, until the formation of the later part of the Gary moraine.

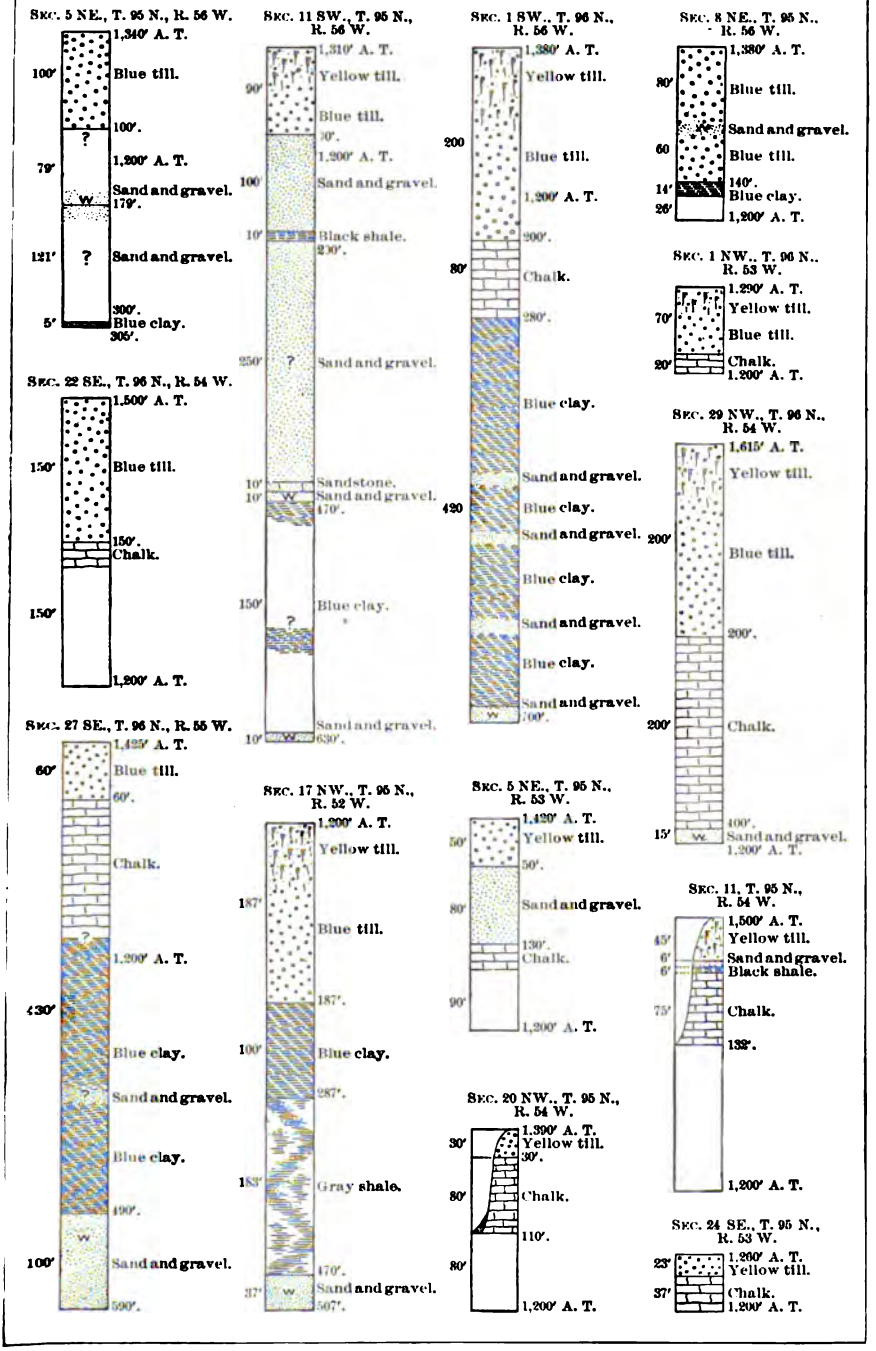
WATER SUPPLY.

Under this head are included the most important economic results of the study of the geology of this area. The subject of water supply is divided into surface waters and underground waters. Under the former are included lakes, springs, and streams, and under the latter are included the supplies which furnish shallow wells, artesian wells, and tubular or pump wells.

SURFACE WATERS.

LAKES.

These receive their waters directly from the rainfall and endure according to the extent of their drainage basin, the depth of their reservoir, and the dryness of successive years. The rainfall of the region varies greatly during different seasons. Its average is about 25 inches. After a succession of wet years, the lake beds over the whole region are filled with water, and in the spring also, if there has been much snow, the same is true. However, in the latter part



LOGS OF WELLS IN YANKTON AND CLAY COUNTIES, SOUTH DAKOTA.

of summer nearly all of them become dry. Some of the more important are marked upon the map as regular lakes. Within the last twenty-five years some lakes have passed through a summer with 10 or 15 feet of water, and a few years later have become dry enough for tillage.

SPRINGS.

Permanent springs are rarely found, but a few occur along the James River and its principal tributaries. They receive their waters from the various formations which are treated more fully under the head of underground waters.

One class of springs which, perhaps, are not often recognized as such derive their waters from the rainfall seeping through the upper part of the drift into the water courses. Since the water from them is contained in isolated basins or waterholes in the water courses, many may not recognize the fact that the water supplied comes from below the surface, but this is doubtless the fact. To the constant movement of the water, more fully described under the head of underground waters, is to be traced the purity of the water in the ponds and their freedom from stagnant properties.

Other springs are derived from the gravel and clay deposits capping the ancient terraces or lining the old water courses of the Glacial epoch. As an example of this may be mentioned a spring in the southwest corner of sec. 34, T. 100 N., R. 59 W., which is supplied from the gravel deposits in an old channel of the James River about 100 feet above the present stream. Another less copious spring appears on sec. 3 of the same township, where the same channel meets the deeper valley of Dry Creek. Another spring from these same deposits appears on or near sec. 15 of the township to the south. It is probable that careful examination would reveal several more of similar origin.

Still other springs derive their waters from the sands below the bowlder clay. These fail to bring water to the surface except where it rests upon underlying clays, probably Cretaceous, although this can not always be easily demonstrated. Springs of this sort have been noted at the base of the bluffs on the right bank of the James River at a number of points between the mouth of Dry Creek and Wolf Creek. It is probable that a further search would discover many more.

A few springs are known to come from joints or porous strata in the chalkstone. Such are found near Scotland and along Turkey Creek. Their waters are frequently unpalatable from impregnation with alum salts.

Other springs seem to be supplied from the sandstone of the Dakota formation. Cases of this kind have been noted a mile or two south

of Elmspring, where the water escapes from the base of the sandstone as it rests upon the shaly clay below. Other springs which we believe are supplied from the same geological stratum are found near Olivet. They are two in number, the smaller appearing 10 or 12 rods southeast of the bridge crossing the James River east of Olivet; the other about a quarter of a mile farther north, within a few rods of the edge of the bottom adjoining the river. Both of these springs or ponds, as they may be called, are surrounded with bulrushes and are of circular form. The water rises nearly to the level of the bottom land, which is 10 feet higher than the ordinary stage of the James River nearby. Since they are more than a half mile from the base of the bluffs on the east, and the water is higher than can be found at ordinary stages in the James River within 2 or 3 miles farther upstream, it seems clear that the supply is derived from a stratum of the Dakota sandstone, and that we have here, as it were, natural artesian wells. The large spring has a diameter of about 150 feet of open area besides that occupied by bulrushes. Quite similar to the Olivet springs is the one 5 miles north of Mitchell, shown on Pl. IX, *B*. It differs only in having higher banks. Pl. X, *A* shows another type, escaping close to Sioux quarzite ledges on Enemy Creek, southeast of Mitchell. It is probable that similar leaks from the artesian stratum escape into the trough of the James River below the water, or at least below the surface. Some of the small marshes which are found upon the flood plain may be supplied from this source, although probably most are supplied from the waters escaping from the sand sheet below the till.

STREAMS.

The James River is the only stream in this area which may be depended upon to contain running water at all times. The lower portions of Wolf Creek, Twelvemile Creek, and Lonetree Creek are rarely entirely dry, but above the last mile or two of their course the water in the latter part of summer rarely flows upon the surface.

UNDERGROUND WATERS.

The most accessible underground waters are those flowing near the surface of the ground or seeping through the upper portion of the till toward a water course, where there are shallow accumulations of sand, which form conduits for it. It flows slowly through the lower portions of these sand accumulations and appears at intervals in waterholes along the upper portions of the more prominent streams. In these it rarely comes forth in sufficient strength to attract attention. Where the slope of the surface is toward an undrained basin, the water, flowing on yellow till, contributes to the level of the water in an open lake until the water level sinks below the surface, as it soon does in the great majority

A. DAKOTA SANDSTONE ON FIRESTEEL CREEK, IN TOWNSHIP 104 NORTH, RANGE 61 WEST.

B. ARTESIAN SPRING, IN TOWNSHIP 104 NORTH, RANGE 60 WEST.

of cases. It may then be drawn upon by shallow wells which for a number of years may be entirely adequate for the demands of neighboring farms, but in time of drought gradually become exhausted. Where the surfaces slope toward a water course, the water accumulates in larger supply, but it also flows away sooner. Shallow wells, therefore, along the ancient water courses which were occupied by streams of considerable size during the presence of glaciers in the vicinity, afford some of the most copious wells in the region, some of them being quite shallow. These shallow wells were the main dependence of the farmers of the region in the early settlement of it. In 1881 and a few years subsequent, water was abundant in these surface wells, but after a series of dry years this supply became exhausted and farmers were forced to go deeper for their water supply.

The next supply was that derived from the sand and gravel at the base of the drift. These are reached by penetrating the till, which is done by boring, often to 300 feet below the surface. This depth would be a serious disadvantage were it not in a measure compensated for by the rise of the water, so that in many such wells the water stands within 5 to 25 feet of the surface; some, in fact, became flowing wells. There are wells of this class in the area which have been flowing for over twenty years. The depth to these subtill waters is shown on Pl. V. As we have elsewhere stated, the thickness of the till varies considerably within short distances. Hence, the depth indicated on the map sometimes may not be within 25 to 50 feet of the point where water will be reached, although in the majority of cases it is believed that it will be much nearer. Moreover, as will be readily understood, the subtill sand sheet is not everywhere filled with water, especially in higher regions. Therefore the sand may be reached and passed through to the Cretaceous shale below without yielding water. This seems to have been true in some cases in the Choteau Creek Hills. On the other hand, flowing wells are frequently found at lower levels. Such areas, however, are of comparatively slight extent, and the pressure head is not level, but slopes irregularly with the surface. This is doubtless due to the slow motion of the water below. The areas where flowing wells from this source have been obtained are indicated on Pl. II. Probably others may be found by boring, especially at intermediate altitudes remote from important streams. In some cases the erosion of the ravine or watercourse is that which renders the flowing wells possible, because it decreases the altitude of the surface while the head remains constant. As we have already stated under General geology, cases are not infrequent where deposits of sand and gravel are locally developed in the till itself. These frequently furnish a copious supply of water, and in such cases wells yield water without entirely penetrating the till. On the other hand, sands below the till are absent at some points. In

such cases no water is likely to be reached short of the main artesian supply. The deep wells supplied from this source are commonly known as tubular wells, though that term strictly indicates the construction of the pumps used. Hence, we may conveniently speak of the Pleistocene subtill sands as the "tubular-well supply."

It seems evident that the original source of this supply is the rainfall, the same as in the case of shallow wells, but it is a more constant supply, because the water enters it more gradually. It is more continuous, and does not waste in evaporation as in shallow wells. It should not, however, be considered inexhaustible, because if a tubular well is drawn upon too freely it may be expected to gradually fail, especially if it is in an elevated region.

The way in which the water enters this stratum is not well understood. In general, the till seems to be so perfectly impervious that, especially at lower levels, it prevents the escape of the water below quite completely. We have before called attention to the joints in the clay, which, at certain times, especially in more abrupt portions of the surface, and after drought, are probably opened sufficiently to allow water to enter from the surface. Besides, it is not improbable that the bottom of the ancient channels may at some points cut through the till to the lower Pleistocene sands in such a way as to add materially to this supply.

WATER FROM THE OLDER STRATA.

In case sands belonging to the Tertiary should be discovered in the region it is likely that they will be closely connected with the lower Pleistocene sands, and hence we need not discuss them separately. The chalkstone of the Colorado formation is porous and water bearing; in fact, springs are occasionally found flowing from it. We have already spoken of springs from it at Scotland. It exists in such detached masses, and wherever it affects wells is so closely underneath the drift that it need not be treated at any length separate from the tubular-well supply.

It has been found convenient in some places to use chalk as a filter to keep out the sand from the bottom of the well. Moreover, there appears in some places, although not certainly in this area, a stratum of sandstone in the chalk which affords water more copiously and may sometimes have a relation similar to that of the Dakota sandstone underneath.

MAIN ARTESIAN SUPPLY.

Those who have studied the matter universally agree that the main artesian supply is from the sandstone and sand beds of the Dakota formation. This remarkable formation is the source of water in Texas and Colorado, as well as in this region. It owes its efficiency to four

A. SHERRILL SPRING, ON LOWER ENEMY CREEK.

B. KILBURN RUN, FED BY KILBURN WELL, NORTH OF MOUNT VERNON, SOUTH DAKOTA.

conditions: (1) Its great extent, underlying most of the Great Plains from the Rocky Mountains to about the ninety-fifth meridian. (2) Its highly elevated western border, located in the moist region of the mountains and crossed by numerous mountain streams. (3) The fact that it is extensively sealed on its eastern margin by the overlapping clays of the Colorado formation, and where that is not the case, by the till sheet of the Glacial epoch. (4) The excavation of wide areas, especially in Dakota, by older streams, so as to bring the land surface below the pressure height or "head" generated by the elevated western border of the formation. From this source also are derived the copious pumping supplies of water over wide areas, where the pressure is not sufficient to produce flowing wells.

Pl. X, *B* gives a vivid impression of the possibilities of such wells. The flow is through a 3-inch pipe and from a depth of only 337 feet. The stream rivals the Firesteel nearby in the amount of flowing water. It is estimated to furnish over 1,000 gallons a minute. Most of the wells in the area are much smaller and are much more convenient for ordinary farm use, besides being more enduring.

The Dakota deposits underlie nearly the entire area treated in this report, but from the relation of pressure to surface the true artesian area is limited approximately as represented upon the map (Pl. II).

In boring wells the term "flow" is used by some persons to indicate that the water has sufficient pressure to rise some distance in the well, but it is more customary to limit the term to those cases in which there is sufficient force for the water to rise to or over the top of the well. From a comparison of the sections of different wells it appears that the sheets of sand are more or less separated by intercalated sheets of clay, the permeable sandy deposits extending out into thin, wing-like sheets. In this way there are in this area at least three horizons with well-marked flows. The first or uppermost of these probably corresponds to the stratum which is exposed above Milltown. This bed, of course, can not hold water under pressure sufficient to produce flowing wells in the vicinity of its exposure where the head is lost by leakage. The second flow is that which supplies most of the wells northeast of the town of Tripp. The third is that probably reached in the deep well at Tripp. Probably others occur still deeper in the southeast portion of the Olivet quadrangle.

From a study of the sections of the wells it is evident that the successive flows rise somewhat toward the exposures of quartzite, but that the higher water-bearing strata considerably overlap those below. In other words, the lowest sandstone stratum of the Dakota does not extend as far northeast by several miles as those higher up. There has been no effort to express on the map the extent of the different water-bearing strata, but they may be inferred from the irregularities in the depths given.

PRESSURE.

From a superficial study of artesian wells it might be thought that the water, especially in particular artesian basins, has the same head or would everywhere rise to the same plane. Such, however, is far from the fact in the wells of South Dakota. In general, the pressure declines toward the margin of the water-bearing strata. This is readily explained, as noted above, in the shallow basins by supposing that the water is moving as a slow current toward leaks along the margin of the formation where it joins the older rocks or where fissures may connect it with the bottom of streams. Each flow, in general, shows this same decline in pressure toward the northeast.

Moreover, from what we have said about the relation of the Dakota sandstone to the Sioux quartzite and Colorado clays, one can easily understand how the lower flows are found to have higher pressure. Their leakage is much less free. Upon the map (Pl. II) there are contours representing the altitude of "head," which in its downward slope east may be regarded as a "hydraulic gradient." From the nature of the case, it would be impossible to represent the pressure for each water-bearing stratum, and we have therefore taken the data from the more important wells; or, in other words, the lines of altitude of "head" may be taken as representing the relative pressure in the more available and accessible stratum. It is not unlikely that the sinking of wells 300 to 500 feet in depth, to the third or fourth flow, may show considerably increased pressures. It will be observed that the lines have a distinct curve toward the south and east. This may be ascribed, especially in the case of the 1,400-foot line, to the fact of locally increased leakage along the James River Valley, together with the general diminution of supply to the south and east in eastern South Dakota.

The pressure in the wells of this area has not been very generally noted. Many of the wells are small and intended simply for farm supply, so that the pressure has not been an important consideration. At Tripp the pressure was 10 pounds and at Scotland perhaps 4 or 5 pounds, soon after the wells were finished, but at present they barely flow. The wells southeast of Parkston are reported to have a pressure of 40 pounds, and at that place 55 pounds has been recorded recently.

VARIATION OF PRESSURE.

This brings us to a consideration of certain influences that affect pressure. Under this head we shall consider, briefly, a variety of influences that have been found to affect pressure, and will give others the cause of which has not been discovered.

(1) Variation in adjacent wells. Places are not infrequent, although not notable in this area, where wells at nearly the same point have

widely different pressure. In some cases it is evident that the wells are supplied from different sources or flows. This conceivably may be true, even when the water is from the same depth; for, as before stated, the water-bearing strata branch, and do not always extend upon the same level. More frequently, however, these wide local variations are due to the pressure from the stronger flow expending itself along the outside of the pipe into an upper stratum of less pressure.

(2) Variation in the same well at different depths. This need not be dwelt upon, for we have already explained how lower strata are more perfectly sealed on their eastward margin and therefore display higher pressure.

(3) Variations in the same well because of wells in the vicinity. The distance to which the influence of the escape of water from a well extends may reasonably be supposed to be directly proportional to the amount of water discharged. We may conceive that the flow of the well produces a depression in the surface, or "head," so to speak, proportional to the amount of water discharged, somewhat as in the case of an opening in the bottom of a reservoir. If the flow is rapid the depression may be great, so that if the well is closed its pressure will be at first, perhaps, several pounds below the original pressure, but as the water flows in from adjacent areas the pressure in the well will gradually regain its former amount. So, if two wells are near each other, we can not expect that the closed pressure of one will approach very closely to the original figure if the other is left open.

(4) Effect from varying barometer. As the pressure taken is with a gage affected by the pressure of the air, it follows that when the barometer is high the pressure of the fluid within will be correspondingly diminished. The influence is, of course, slight, and will be overlooked unless the pressure in the well is very weak. Under such circumstances, however, an increase of the pressure of the air may sometimes be sufficient to stop the flow and, conversely, a low barometer may increase the flow.

(5) Periodic variations. In a number of the weaker wells there has not only been a decline of pressure, but from time to time an increase. This increase has been in some cases related to the time of year, the spring being sometimes marked by a stronger flow. This again varies according to years, and it is believed to be most satisfactorily explained by supposing that the water is obtained from the melting of snows or from streams subject to floods.

(6) Effect of varying leakage in the vicinity. This has been observed in wells near the Missouri River. When the river is high the pressure in the wells increases. It is easily explained by supposing that there are points of leakage underneath the surface of the river, and that the increase of hydrostatic pressure from the stream checks the leakage to such an extent that it increases the pressure in adjacent wells. While

this has not been noted in the area, it is not improbable that examples occur near the James River. This variation, of course, is slight, and would be unnoticed except in very weak wells.

Upon the map (Pl. II) approximate depth to the surface of the Dakota sandstone is represented. As was stated in the discussion of that formation, this does not always directly mark the upper limits, but more definitely the level from which flowing wells may be obtained. In cases where water is not found at the depth indicated the boring may be hopefully carried through lower horizons to bed rock, the depth of which is shown on Pl. IV. In the southeastern corner of the area and along its western side the Dakota sandstone is thicker and probably carries more water-bearing strata.

HINTS ON THE CONSTRUCTION OF WELLS.

Although the practical application of the following hints belongs to the work of the well-borer, and may be discussed more efficiently from the standpoint of an engineer, yet they may be advantageously noted here in connection with the geological facts.

(1) Since the pressure in the upper flows is less than in the lower by many pounds to the inch, it is very important that the communication between the lower flows and the higher should be entirely cut off. Otherwise the full pressure from the lower stratum will not be observed at the mouth of the well, but will expend itself by leaking into the strata below the surface. The desire of the well-digger to keep his pipe loose may tempt him to leave the bore too large—hence the danger we speak of.

(2) It is very desirable that the larger pipe lining the bore be firmly fixed in the hard stratum above the water-bearing rock. This may be done in most localities, as a compact stone is found just above the porous sands which bring the water. Much depends upon this, for if a pipe be left loose, and the opening in the rock left incompletely stopped, water is likely to escape around the pipe and, if not checked, may eventually destroy the well.

(3) A well should be sunk as rapidly as consistent with good work, especially after water has been reached. Otherwise, the great pressure of the water may cause it to erode an irregular opening and prevent the accomplishment of the two points already given.

PERMANENCE OF ARTESIAN SUPPLY.

All natural products are liable to exhaustion. With gold, coal, and other metallic products no general rules can be laid down by which we may foretell how soon the supply may fail. With water it is otherwise. As we have already said, multiplication of wells must tend to exhaustion. If, however, the loss by wells and leakage does

not exceed the annual supply which enters the formation on the west, an equilibrium may be gained which will be as constant as in a river. It may be expected to have similar fluctuations. At present the pressure in wells in the area discussed is generally slightly declining. Some wells of original low pressure have ceased to flow, as at Scotland, Tripp, in sec. 12, T. 95 N., R. 56 W., and in other places, but the great majority have failed but little. There is no apprehension of early failure.

From the sheet-like form of the water strata and their nearly horizontal position, the decline of pressure will necessarily be very regular and gradual. If, to illustrate, a well having a pressure of 50 pounds should show a decline of 2 pounds a year, under similar conditions it would last twenty-five years with gradually decreasing flow. Moreover, it is possible, if not probable, from the wide extent of the Dakota sandstone at high altitudes toward the west, that there is a reserve supply which may become more available as the head declines.

Many of the reported cases of failure from other portions of the artesian area have been shown to be due to stoppage by sand or to subterranean leakage resulting from the rusting of the pipe or imperfect construction, and sometimes from the breaking of the pipe by caving.

Until more is known of the circumstances controlling the supply little more can be said upon this point.

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1895.

Sixteenth Annual Report of the United States Geological Survey, 1894–95, Part II. Papers of an economic character, 1895; octavo, 598 pp.

Contains a paper on the public lands and their water supply, by F. H. Newell, illustrated by a large map showing the relative extent and location of the vacant public lands; also a report on the water resources of a portion of the Great Plains, by Robert Hay.

A geological reconnoissance of northwestern Wyoming, by George H. Eldridge, 1894; octavo, 72 pp. Bulletin No. 119 of the United States Geological Survey; price, 10 cents.

Contains a description of the geologic structure of portions of the Bighorn Range and Bighorn Basin, especially with reference to the coal fields, and remarks upon the water supply and agricultural possibilities.

Report of progress of the division of hydrography for the calendar years 1893 and 1894, by F. H. Newell, 1895; octavo, 176 pp. Bulletin No. 131 of the United States Geological Survey; price, 15 cents.

Contains results of stream measurements at various points, mainly within the arid region, and records of wells in a number of counties in western Nebraska, western Kansas, and eastern Colorado.

1896.

Seventeenth Annual Report of the United States Geological Survey, 1895–96, Part II, Economic geology and hydrography, 1896; octavo, 864 pp.

Contains papers on "The underground water of the Arkansas Valley in eastern Colorado," by G. K. Gilbert; "The water resources of Illinois," by Frank Leverett; and "Preliminary report on the artesian waters of a portion of the Dakotas," by N. H. Darton.

Artesian-well prospects in the Atlantic Coastal Plain region, by N. H. Darton, 1896; octavo, 230 pp., 19 plates. Bulletin No. 138 of the United States Geological Survey; price, 20 cents.

Gives a description of the geologic conditions of the coastal region from Long Island, N. Y., to Georgia, and contains data relating to many of the deep wells.

Report of progress of the division of hydrography for the calendar year 1895, by F. H. Newell, hydrographer in charge, 1896; octavo, 356 pp. Bulletin No. 140 of the United States Geological Survey; price, 25 cents.

Contains a description of the instruments and methods employed in measuring streams and the results of hydrographic investigations in various parts of the United States.

1897.

Eighteenth Annual Report of the United States Geological Survey, 1896–97, Part IV, Hydrography, 1897; octavo, 756 pp.

Contains a "Report of progress of stream measurements for the calendar year 1896," by Arthur P. Davis; "The water resources of Indiana and Ohio," by Frank Leverett; "New developments in well boring and irrigation in South Dakota," by N. H. Darton; and "Reservoirs for irrigation," by J. M. Schuyler.

1898.

Nineteenth Annual Report of the United States Geological Survey, 1897–98, Part IV, Hydrography, 1898; octavo, 814 pp.

Contains a "Report of progress of stream measurements for the calendar year 1898," by F. H. Newell and others; "The rock waters of Ohio," by Edward Orton; and "A preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian," by N. H. Darton.

1900.

Twentieth Annual Report of the United States Geological Survey, 1898–99, Part IV, Hydrography, 1900; octavo, 660 pp.

Contains a "Report of progress of stream measurements for the calendar year 1899," by F. H. Newell, and "Hydrography of Nicaragua," by A. P. Davis.

WATER-SUPPLY AND IRRIGATION PAPERS, 1896–1900.

This series of papers is designed to present in pamphlet form the results of stream measurements and of special investigations. A list of these, with other information, is given on the outside (or fourth) page of this cover.

Survey bulletins can be obtained only by prepayment of cost, as noted above. Money should be transmitted by postal money order or express order, made payable to the Director of the United States Geological Survey. Postage stamps, checks, and drafts can not be accepted. Correspondence relating to the publications of the Survey should be addressed to **The Director, United States Geological Survey, Washington, D. C.**

WATER-SUPPLY AND IRRIGATION PAPERS.

1. Pumping water for irrigation, by Herbert M. Wilson, 1896.
2. Irrigation near Phœnix, Arizona, by Arthur P. Davis, 1897.
3. Sewage irrigation, by George W. Rafter, 1897.
4. A reconnoissance in southeastern Washington, by Israel C. Russell, 1897.
5. Irrigation practice on the Great Plains, by E. B. Cowgill, 1897.
6. Underground waters of southwestern Kansas, by Erasmus Haworth, 1897.
7. Seepage waters of northern Utah, by Samuel Fortier, 1897.
8. Windmills for irrigation, by E. C. Murphy, 1897.
9. Irrigation near Greeley, Colorado, by David Boyd, 1897.
10. Irrigation in Mesilla Valley, New Mexico, by F. C. Barker, 1898.
11. River heights for 1896, by Arthur P. Davis, 1897.
12. Underground waters of southeastern Nebraska, by N. H. Darton, 1898.
13. Irrigation systems in Texas, by William Ferguson Hutson, 1898.
14. New tests of pumps and water lifts used in irrigation, by O. P. Hood, 1898.
15. Operations at river stations, 1897, Part I, 1898.
16. Operations at river stations, 1897, Part II, 1898.
17. Irrigation near Bakersfield, California, by C. E. Grunsky, 1898.
18. Irrigation near Fresno, California, by C. E. Grunsky, 1898.
19. Irrigation near Merced, California, by C. E. Grunsky, 1899.
20. Experiments with windmills, by Thomas O. Perry, 1899.
21. Wells of northern Indiana, by Frank Leverett, 1899.
22. Sewage irrigation, Part II, by George W. Rafter, 1899.
23. Water-right problems in the Bighorn Mountains, by Elwood Mead, 1899.
24. Water resources of the State of New York, Part I, by George W. Rafter, 1899.
25. Water resources of the State of New York, Part II, by George W. Rafter, 1899.
26. Wells of southern Indiana (continuation of No. 21), by Frank Leverett, 1899.
27. Operations at river stations, 1898, Part I, 1899.
28. Operations at river stations, 1898, Part II, 1899.
29. Wells and windmills in Nebraska, by Erwin Hinckley Barbour, 1899.
30. Water resources of the Lower Peninsula of Michigan, by Alfred C. Lane, 1899.
31. Lower Michigan mineral waters, by Alfred C. Lane, 1899.
32. Water resources of Puerto Rico, by H. M. Wilson, 1900.
33. Storage of water on Gila River, Arizona, by J. B. Lippincott, 1900.
34. Geology and water resources of southeastern S. Dak., by J. E. Todd, 1900.

In addition to the above, there are in various stages of preparation other papers relating to the measurement of streams, the storage of water, the amount available from underground sources, the efficiency of windmills, the cost of pumping, and other details relating to the methods of utilizing the water resources of the country. Provision has been made for printing these by the following clause in the sundry civil act making appropriations for the year 1896–97:

Provided, That hereafter the reports of the Geological Survey in relation to the gaging of streams and to the methods of utilizing the water resources may be printed in octavo form, not to exceed 100 pages in length and 5,000 copies in number; 1,000 copies of which shall be for the official use of the Geological Survey, 1,500 copies shall be delivered to the Senate, and 2,500 copies shall be delivered to the House of Representatives, for distribution. [Approved June 11, 1896; Stat. L., vol. 29, p. 453.]

The maximum number of copies available for the use of the Geological Survey is 1,000. This number falls far short of the demand, so that it is impossible to supply all requests. Attempts are made to send these pamphlets to persons who have rendered assistance in their preparation through replies to schedules or who have furnished data. Requests specifying a certain paper and stating a reason for asking for it are granted whenever practicable, but it is impossible to comply with general requests, such as to have all of the series sent indiscriminately.

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THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
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DEPARTMENT OF THE INTERIOR

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AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 35

OPERATIONS AT RIVER STATIONS, 1898.—PART I

WASHINGTON
GOVERNMENT PRINTING OFFICE
1900

IRRIGATION REPORTS.

The following list contains titles and brief descriptions of the principal reports relating to water supply and irrigation, prepared by the United States Geological Survey since 1890:

1890.

First Annual Report of the United States Irrigation Survey, 1890; octavo, 132 pp.

Printed as Part II, Irrigation, of the Tenth Annual Report of the United States Geological Survey, 1888-89. Contains a statement of the origin of the Irrigation Survey, a preliminary report on the organization and prosecution of the survey of the arid lands for purposes of irrigation, and report of work done during 1890.

1891.

Second Annual Report of the United States Irrigation Survey, 1891; octavo, 336 pp.

Published as Part II, Irrigation, of the Eleventh Annual Report of the United States Geological Survey, 1889-90. Contains a description of the hydrography of the arid region and of the engineering operations carried on by the Irrigation Survey during 1890; also the statement of the Director of the Survey to the House Committee on Irrigation, and other papers, including a bibliography of irrigation literature. Illustrated by 29 plates and 4 figures.

Third Annual Report of the United States Irrigation Survey, 1891; octavo, 576 pp.

Printed as Part II of the Twelfth Annual Report of the United States Geological Survey, 1890-91. Contains "Report upon the location and survey of reservoir sites during the fiscal year ended June 30, 1891," by A. H. Thompson; "Hydrography of the arid regions," by F. H. Newell; "Irrigation in India," by Herbert M. Wilson. Illustrated by 93 plates and 190 figures.

Bulletins of the Eleventh Census of the United States upon irrigation, prepared by F. H. Newell; quarto.

No. 85, Irrigation in Arizona; No. 90, Irrigation in New Mexico; No. 85, Irrigation in Utah; No. 107, Irrigation in Wyoming; No. 153, Irrigation in Montana; No. 157, Irrigation in Idaho; No. 163, Irrigation in Nevada; No. 178, Irrigation in Oregon; No. 193, Artesian wells for irrigation; No. 198, Irrigation in Washington.

1892.

Irrigation of western United States, by F. H. Newell; extra census bulletin No. 23, September 9, 1892; quarto, 22 pp.

Contains tabulations showing the total number, average size, etc., of irrigated holdings, the total area and average size of irrigated farms in the subhumid regions, the percentage of number of farms irrigated, character of crops, value of irrigated lands, the average cost of irrigation, the investment and profits, together with a resume of the water supply and a description of irrigation by artesian wells. Illustrated by colored maps, showing the location and relative extent of the irrigated areas.

1893.

Thirteenth Annual Report of the United States Geological Survey, 1891–92, Part III, Irrigation, 1893; octavo, 486 pp.

Consists of three papers: "Water supply for irrigation," by F. H. Newell; "American irrigation engineering" and "Engineering results of the Irrigation Survey," by Herbert M. Wilson; "Construction of topographic maps and selection and survey of reservoir sites," by A. H. Thompson. Illustrated by 77 plates and 110 figures.

A geological reconnaissance in central Washington, by Israel Cook Russell, 1893; octavo, 108 pp., 15 plates. Bulletin No. 108 of the United States Geological Survey; price, 15 cents.

Contains a description of the examination of the geologic structure in and adjacent to the drainage basin of Yakima River and the great plains of the Columbia to the east of this area, with special reference to the occurrence of artesian waters.

1894.

Report on agriculture by irrigation in the western part of the United States at the Eleventh Census, 1890, by F. H. Newell, 1894; quarto, 283 pp.

Consists of a general description of the condition of irrigation in the United States, the area irrigated, cost of works, their value and profits; also describes the water supply, the value of water, of artesian wells, reservoirs, and other details; then takes up each State and Territory in order, giving a general description of the condition of agriculture by irrigation, and discusses the physical conditions and local peculiarities in each county.

Fourteenth Annual Report of the United States Geological Survey, 1892–93, in two parts; Part II, Accompanying papers, 1894; octavo, 597 pp.

Contains papers on "Potable waters of the eastern United States," by W J McGee; "Natural mineral waters of the United States," by A. C. Peale; "Results of stream measurements," by F. H. Newell. Illustrated by maps and diagrams.

(Continued on third page of cover.)

DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 35

WASHINGTON
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1900

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

OPERATIONS AT RIVER STATIONS, 1899

A REPORT OF THE

DIVISION OF HYDROGRAPHY

OF THE

UNITED STATES GEOLOGICAL SURVEY

PART I

WASHINGTON

GOVERNMENT PRINTING OFFICE

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, March 1, 1900.

SIR: I have the honor to transmit herewith a manuscript giving the results of operations at the river stations in the eastern portion of the country during the calendar year 1899, together with related data, for publication in the series of papers upon water supply and irrigation. The data for the central and western portions of the country will be transmitted as the succeeding numbers of the series.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

OPERATIONS AT RIVER STATIONS, 1899.

PART I.

INTRODUCTION.

The following pages contain descriptions of the river stations maintained during 1899 by the United States Geological Survey, together with tables of the average daily height of water and results of measurements of discharge. The rating tables constructed from the latter and applicable in general for the calendar year will be given at the end of the publication. Similar facts have been printed for the year 1896 in Water-Supply Paper No. 11, for 1897 in Water-Supply Papers Nos. 15 and 16, and for 1898 in Water-Supply Papers Nos. 27 and 28. The stations have been arranged in geographic order. A description of each station is given, together with all of the discharge measurements, followed by the tables of gage heights and ratings.

The material above noted consists essentially of the results of operations at the river stations, and forms the basis for computations of daily, monthly, and annual flow. In order to make these necessary computations considerable time and labor is involved and the resulting facts can be most clearly and concisely given by diagrams. The preparation of the computations and the diagrams necessitates unavoidable delays, and therefore it has been the custom to present the facts, such as are given herewith, as soon as possible after the close of the calendar year, so that the original data may be available at an early date to all who are concerned with their use. While these original figures are being printed the computations of final results are being prepared, and, with the illustrations, have in the past been made to form a part of the annual report of the Director of the Geological Survey. For example, the results for 1896, mentioned above, as given in Water-Supply Paper No. 11, are fully discussed in Part IV of the Eighteenth Annual Report; the original data for 1897, given in Water-Supply Papers Nos. 15 and 16, are published in final form in the Nineteenth Annual Report, Part IV, and the data for 1898, given in Water-Supply Papers Nos. 27 and 28, are published

in the Twentieth Annual Report, Part IV. In the same way the figures herewith given form the basis for conclusions being prepared for publication in Part IV of the Twenty-first Annual Report.

ACKNOWLEDGMENTS.

Most of the measurements herewith presented have been obtained through local hydrographers, a comparatively small part of the work having been conducted directly from the office of the Geological Survey at Washington. Acknowledgment is therefore due to each of these persons individually. Thanks should also be extended to individuals and corporations who have cooperated in various ways, either by furnishing readings of height of water or assisting in transportation. The following list gives the names of the resident hydrographers or persons cooperating, this being arranged alphabetically by States.

Arizona: W. A. Farish, civil engineer, Phenix.

California: J. B. Lippincott, civil engineer, Los Angeles.

Colorado: A. L. Fellows, civil engineer, Denver.

Georgia and Alabama: Prof. B. M. Hall, civil engineer, Atlanta, and Prof. W. S. Yeates, State geologist, Atlanta.

Idaho: N. S. Dils, civil engineer, Caldwell.

Kansas: W. G. Russell, Russell; Prof. E. C. Murphy, State University, Lawrence.

Maryland: Prof. W. B. Clark, State geologist, Baltimore.

Montana: S. M. Emery, director experiment station, Bozeman; Prof. Samuel Fortier, Bozeman; Prof. Fred. D. Smith, Missoula.

Nebraska: Prof. O. V. P. Stout, State University, Lincoln, assisted by Adna Dobson and Glenn E. Smith.

Nevada: L. H. Taylor, civil engineer, Golconda.

New Mexico: P. E. Harroun, civil engineer, Albuquerque.

North and South Carolina: Prof. J. A. Holmes, State geologist, Chapel Hill, North Carolina, assisted by E. W. Myers.

Texas: Prof. Thomas U. Taylor, State University, Austin.

Utah: Prof. Samuel Fortier, civil engineer, Corinne, assisted by J. L. Rhead and J. S. Baker; later, Prof. George L. Swendsen, Logan.

Virginia and West Virginia: Prof. D. C. Humphreys, Washington and Lee University, Lexington, Virginia.

Washington: Sydney Arnold, civil engineer, North Yakima; William J. Ware, civil engineer, Port Angeles.

Wyoming: A. J. Parshall, civil engineer, Cheyenne.

In a number of instances related data have been inserted, such, for example, as results of computation of daily flow at mill dams, made by local engineers, and data of river heights obtained from the United States Weather Bureau, or Corps of Engineers, United States Army. Reference to these facts, mainly unpublished, has been, or will be, made in other publications of this survey, and they are therefore placed in consecutive order for convenience of reference.

The methods of measuring the discharge of various streams and of

preparing the computations have been described on pages 18 to 30 of the Nineteenth Annual Report, Part IV, and on pages 20 to 22 of the Twentieth Annual Report, Part IV. The tables used in facilitating computations are also given on pages 29 to 32 of Bulletin No. 140.

CLASSIFICATION OF FIELD WORK.

In order to make a comprehensive study of the surface waters of the United States four classes of work are in hand:

1. Maintenance of long-record river stations.
2. Maintenance of short-record river stations.
3. Reconnaissance along streams.
4. Detailed reservoir surveys.

The long-record river stations are designed to show the influence of climatic fluctuations upon the volume of a river at a given locality. Only a few of these long-record stations can be maintained in any one State or section. Under this head are included only the localities where the conditions are highly favorable for accuracy of results as furnishing a standard of comparison. At such points especial care is taken to verify the gage readings and to make frequent measurements of discharge to give assurance that the rating table is correct. From the results obtained here it is possible to compare one year with another and ascertain which are years of high or low water or of medium flow.

The short-record river stations are established for the purpose of obtaining the flow at a given point for a short period. Each short-record station is discontinued as soon as the results are considered sufficient for probable industrial development. Reasonable care is taken to verify the results at these stations, but necessarily not the same refinement needed as in the case of the long-record stations.

Reconnaissance along important streams is systematically carried forward whenever the season is favorable, preferably during low water. Measurements of discharge are made wherever practicable during the progress of this work and observation of height maintained at some one point during the time of the reconnaissance. At important points level lines are run to obtain the fall, particularly where water power may be developed.

Reservoir sites are being examined and surveyed in various parts of the country whenever suitable localities are discovered by reconnaissance or are brought to attention in other ways. Contour maps are prepared of the lands to be flooded, showing the capacity of the reservoir at various depths. More detailed surveys are also made at the dam sites, and in some cases holes drilled down to and into the bed rock to ascertain the character of the foundations. From the information thus obtained estimates of cost are made. The matter is more fully described in the Twentieth Annual Report, Part IV, pages 25 to 43.

ACCURACY OF RESULTS.

In making the survey and examinations of the flow of streams in various parts of the United States the object in view has been to obtain facts of general application at a cost commensurate with the probable application of the results. It is recognized that with a given expenditure the number of measurements made will depend largely upon the accuracy and precautions employed, and the question at once arises as to what degree of precision should be sought. For example, to ascertain the flow of water at a certain point within 5 per cent of the actual flow may cost $10; within 3 per cent, $25; within 2 per cent, $100, and so on, the cost increasing in an ascending ratio as an approach is made to absolute accuracy. In the example given it is a matter of judgment whether to make measurements at a cost of $100 at ten points within 5 per cent of the flow, or at one point within 2 per cent. For general information concerning the hydrography of the country, such as that sought by this survey, it is obvious that the measurements at the ten points are better than the single measurement of greater accuracy; on the other hand, conditions may be imagined, for example, where water or power is being purchased, when the more expensive single measurement is important.

It is impracticable to assign definite limits to the degree of accuracy of the measurements and computations of river flow, since circumstances vary widely, but as a rule the limit has been set, as above stated, that they shall be within the range of ordinary practical application. The low-water flow or the floods of a given season are never repeated, being higher or lower in subsequent years. By continuing measurements through a decade the range within general limits is known, but may be passed during the succeeding decade. Great accuracy, therefore, in ascertaining the flow at any given time is not necessary for drawing general conclusions, as various assumptions must enter to modify the application of the facts.

In stating results of discharge measurements whole numbers have been used and decimals dropped from the figures obtained by computation. This rule is applied in all cases where the flow exceeds 10 cubic feet per second; where it is less than this decimals may or may not be used, although even here a false conception of accuracy may be given. In obtaining averages or totals representing the flow through considerable periods of time there may be some discrepancies involved through this omission of fractions, but it is not believed that the practical value of the work can be improved by introducing into the computation a higher degree of refinement than is possible or desirable in the field work.

EXPENSE OF MAINTAINING STATIONS.

During 1899 blank forms were sent to all resident hydrographers of the Geological Survey, with the request that they give a full description of each station, with reasons for its establishment and maintenance, together with an itemized statement of the costs incurred in making the measurements and in computing the results. These estimates have been compared with the actual expense incurred during the calendar year, and the results have been analyzed to ascertain what may be called the normal cost of maintaining river stations in various parts of the United States, and to ascertain which of the stations were requiring an expenditure out of proportion to the value of the results.

Whenever the cost of a station is excessive, a careful study of the necessity of that station has been made to determine whether the data obtained are of sufficient value to warrant the extra expenditure. In a few cases it has seemed advisable to discontinue stations on account of the expense of maintenance; but on the whole the result of the analysis has been gratifying, inasmuch as it has shown very few stations which could be considered excessively expensive, and in most of these cases the results obtained have been considered sufficiently valuable to warrant their continuance.

The conditions obtaining in the various parts of the country are so different that the annual cost of maintenance is not fairly comparable. This difference is due to several causes, the chief of which is the great distance between stations in some of the Western States when compared with stations in the Eastern States. This makes additional expense for railroad fare and also for services for the increased time spent in traveling. In most States passes are granted the hydrographers by the railroad companies when upon official business, but this is not true in all States. The beds of some rivers are rocky and permanent in character, necessitating only a few measurements a year, while others are sandy and shifting, requiring many measurements in order to construct discharge curves of any value. An extreme example of the latter case is the Gila River upon which measurements were made nearly every day in the year. The pay of the local observer varies with the distance he is obliged to travel daily to reach the gage.

For the reasons given above, the country has been divided into several sections according to the conditions at the stations. All of the stations in the States bordering on the Atlantic Ocean are considered in one class. These are 57 in number and are under the charge of 4 resident hydrographers. The rivers in the northern part of this section, as far south as Virginia, have as a rule been gaged at points where their beds are rocky, and require only about 4 measurements a

year in order to construct reliable discharge curves, as the curves constructed in the previous years need few changes. South of Virginia the gagings have been made where the beds of the rivers are for the most part soft and changeable, requiring from 6 to 8 measurements a year.

The normal cost of each gaging in the Atlantic States is $11.50. This includes every expense incident to the gaging, and may be divided approximately as follows:

Hydrographer's services in the field	$5.00
Hydrographer's services for computation	2.00
Services of assistant	.50
Cost of local transportation	1.00
Sundry expenses, including board, lodging, etc	3.00
Total	11.50

Hydrographers are obliged to travel, on the average, 200 miles for each gaging, but with few exceptions passes have been granted.

The pay of the observer averages $36 a year. This makes the total cost of an ordinary station in the Atlantic States $82 if 4 gagings are made during the year and $105 if 6 gagings are made.

The river stations in Kansas and Nebraska are in general under the same conditions, and are here considered together. The river beds are more or less changeable, so that, in order to obtain reliable discharge curves, it is necessary to make from 10 to 20 gagings a year at each station, with an average of about 12. The normal cost of each gaging is $12, divided in about the same proportion as in the Atlantic States. For the ordinary stations, therefore, the total cost of gaging for one year would be $144, and adding $40, the average cost of observers' services for one year in this section, gives $184 as the total cost of maintaining the station.

In Colorado the character of the river beds varies considerably in the different parts of the State. Some have a rocky, permanent bed, and others a soft, changeable one, requiring frequent gagings. For this reason the number of gagings required each year at the different stations varies from 2 to 10, with an average of about 6. The average cost of making a measurement is $13; the average cost of observations is $30, making a total cost of $108 for one year. The expense incurred in 1899 has not been as great as here mentioned, as fewer measurements per year have been made.

In Montana, at those stations under the charge of Prof. Fred. D. Smith, from whom reports have been received, the average cost of a gaging is found to be $10; and allowing 10 measurements a year and $30 for observations, the normal cost of maintaining a station for one year is $130.

In Wyoming the average cost of gagings is $30. Allowing 7 measurements a year and $26 for observations, this makes $236 as the normal

cost of maintaining a station for one year. This large expenditure is necessitated by the great distances traveled.

In Idaho the average cost of making a gaging is $20. Allowing 6 measurements a year at each station and $36 for observers, we have $156 as the normal cost of each station for one year.

In California we can say, roughly, that the average cost of a gaging is $30, and making 10 measurements a year; and paying $36 for observers, we have a total cost of $336 a year as the expense of maintaining a station.

These comparisons have been made in order that some idea might be obtained as to the proper cost of maintaining stations. If the cost of any particular station is much higher than the normal cost of stations in that section, it is important that a careful study be made to determine whether or not the measurements are of such value as to warrant the additional expenditure. If not, the station should be discontinued.

DETERMINATION OF DISCHARGE FROM SLOPE.

At various times attempts have been made to obtain data as to slope or fall per mile of the water surface of various rivers, in order to use this factor in estimates of the flow of the stream, and thus make comparison with the discharge as measured by current meters. It has been quite difficult, however, to do this, and the results have been somewhat unsatisfactory, owing to the uncertainty in determining the slope of the stream, considerable latitude of judgment being possible.

Careful leveling along the banks of most streams of moderate size shows that the water surface is alternately approximately level, then has a distinct fall, and again is nearly level; in other words, as expressed in the South, the stream consists alternately of pools and riffles. These may be imperceptible to the eye, but are detected by careful leveling. In determining the slope of the stream the question therefore arises as to whether this shall be determined for the immediate proximity of a given cross section, either at a pool or a riffle, or be taken to include a number of these, and thus extend several thousand feet or even several miles. On the selection of this distance depends, to a large extent, the slope of the stream, the amount varying within wide limits.

The desirability of again taking up this matter was brought to the attention of this office in July, 1899, by Mr. Desmond FitzGerald, chief engineer, to the special commissioners of the Chicago Drainage Canal. Instructions were sent to each field party to endeavor to make such measurements wherever it could be done without notable increase of cost. So many practical difficulties were encountered it has been found that for these observations to have value they should be made by a

field party especially equipped for the purpose and provided with appliances such as are rarely at hand in making ordinary meter measurements.

A few such measurements were made during the past season by different hydrographers, and they will now be considered. The following abbreviations will be used in this connection: D=discharge; A=area, in square feet; V=velocity, in feet per second; W=width, in feet, or practically wetted perimeter; $R=\frac{A}{W}$, hydraulic mean radius; S=slope; n=coefficient of roughness. Kutter's formula has the form $V=C\sqrt{R\,S}$, in which C is a constant to be found.

Etowah River at Canton, Georgia.—On September 5, 1899, B. M. Hall made a survey of this river to find the correct value of n for a 1,500-foot section along the stream. After measuring 1,500 feet, running levels, and placing temporary gage at upper point, he did not have time to make a discharge measurement, but applied the slope to the measurement made August 28, 1897, when the following were found: Gage height, 0.30 foot; area, 423 square feet; mean velocity, 1.061 feet per second; discharge, 449 second-feet. The slope was 0.06 foot in 1,500 feet=0.00004. W=115; therefore $R=\frac{423}{115}=3.68$, and $\sqrt{R\,S}=0.012132$. Substituting in the formula $V=C\sqrt{R\,S}$, we get C=87.4, and from the table in Trautwine, 17th edition, page 276, we find n=0.022.

Loup River at Columbus, Nebraska.—A series of slope measurements to determine the value of n were made by Glenn E. Smith, under the direction of Prof. O. V. P. Stout, of the University of Nebraska, at the gaging station on Loup River. Gage heights were taken on two gages, the auxiliary gage being placed 1,200 feet downstream from the main gage rod. The following were the three observations:

Measurements of Loup River at Columbus, Nebraska.

Date.	Main gage.	Lower gage.	Width.	Area.	Mean velocity.	Discharge.	R
1899.	*Feet.*	*Feet.*	*Feet.*	*Square feet.*	*Feet per second.*	*Second-feet.*	
Sept. 3	4.40	3.30	525	875	2.17	1,902	1.67
Sept. 17	4.40	3.31	525	826	2.23	1,840	1.57
Oct. 5	4.60	3.52	525	953	2.52	2,402	1.81

The following are the computations for the three days: September 3: $S=\frac{1.1}{1,200}=0.00093$; R=1.67; V=2.17. Substituting in the formula $V=C\sqrt{R\,S}$, we obtain C=55.0, and from the table n=0.028.

September 17: S=0.00091; R=1.57; V=2.23. C, therefore, =59.0 and n=0.026.

October 5: S=0.00090; R=1.81; V=2.52. C is found to equal in this case 62.3 and n = 0.026.

Niobrara River at Fort Niobrara, Nebraska.—The following table shows the results of similar measurements made on this river under the direction of Professor Stout. All gage heights are referred to the zero of the main gage. The upper auxiliary gage is 600 feet above and the lower auxiliary gage 600 feet below the main rod.

Measurements of Niobrara River at Fort Niobrara, Nebraska.

Date.	Main gage.	Upper gage.	Lower gage.	Area.	Mean velocity.	Discharge.	Width.	R
1899.	*Feet.*	*Feet.*	*Feet.*	*Square feet.*	*Feet per second.*	*Second-feet.*	*Feet.*	
Aug. 30	1.35	2.32	0.60	196	3.57	700	154	1.27
Sept. 13	1.15	2.20	.60	200	3.47	695	154	1.30
Sept. 26	1.05	2.10	.40	198	3.70	732	154	1.29
Oct. 7	1.15	2.05	.55	215	3.61	776	154	1.40
Oct. 20	.80	2.08	.30	199	4.27	849	154	1.29

As there were three gages read, three different slopes can be determined, as follows: Between the upper and middle gage, between the middle and lower gage, and, finally, between the upper and lower gage. They do not correspond well, as shown in the table immediately following, the slope between the middle and lower gage being constantly less than the slope between the upper and middle gage, and of course the slope between the upper and lower gage is the mean between them.

Comparison of slope measurements at Fort Niobrara, Nebraska.

Gage rod.	Aug. 30.	Sept. 13.	Sept. 26.	Oct. 7.	Oct. 20.
Upper and middle	0.00161	0.00175	0.00175	0.00150	0.00213
Middle and lower	.00125	.00091	.00109	.00100	.00083
Lower and upper	.00143	.00133	.00142	.00125	.00148

The following determinations of the values of C and n are based on the slope as found by the readings on the upper and lower gages. The computations are not carried out, but the results are shown in the following table:

Table showing values of C and n.

	C	n
1899.		
August 30	84.1	0.018
September 13	83.5	.018
September 26	86.8	.018
October 7	86.5	.018
October 20	97.7	.016

One comparison is made between the values of C and n as determined by considering the three different slopes for a single measurement, and for this purpose the gaging on September 13 is used. On this date R=1.30; V=3.47; S, for upper and middle gage, =0.00175; C is found to equal 73.5 and n 0.020. For middle and lower rod, S=0.00091, and C, therefore, =101.0, and n= 0.015. The following table shows these values of C and n for the three slopes on September 13:

Table showing values of C and n on September 13, 1899.

Gage rod.	C	n
Upper and middle	73.5	0.020
Middle and lower	101.0	.015
Lower and upper	83.5	.018

For comparison with results obtained on September 13 it is assumed that the slope determined was made between the upper and lower gages 0.00133. Substituting in Kutter's formula the value of n, as found from the determinations of the slope of the upper and middle rod, we get a discharge of 840 second-feet. Assuming the same slope as above—that is, between the upper and lower rod—and taking the value of n as found between the middle and lower rod, =0.015, and substituting again in Kutter's formula, we get a discharge of 610 second-feet. These latter results are not satisfactory. In this case, with 0.015, 0.018, 0.020 as the three assumed values of n, we get discharges of 610, 695, and 840 second-feet, respectively. The measured discharge, as determined by current meter, for this date was 695 second-feet.

Readings on slope gages were taken for a short period in 1896 on Frenchman River, at Palisade, Nebraska, as shown in the Eighteenth Annual Report, Part IV, page 198, and in Water-Supply Paper No. 11, page 56.

Bear River at Battlecreek, Idaho, and Collinston, Utah.—Measurements of the fall of the surface of Bear River at Battlecreek, Idaho, and at Collinston, Utah, were made by Prof. Samuel Fortier. Stakes were driven into the channel of the stream about 10 feet from each shore line, at points 100 feet below and 100 feet above the cable suspended across the stream. These four stakes were pointed on the top and driven about 1.5 inches below the surface of the water. A small wire nail was driven into the top of each stake until level with the surface of the water, allowance being made for the pulsation of the surface. The elevations of the tops of these nails were then carefully ascertained with a level.

At Battlecreek, Idaho, the bed of Bear River consists of clay near the right bank, small cobblestones in the center, and gravel and pebbles near the left side. The banks are somewhat irregular. The fall, S = 0.00062; water area, A = 443 square feet; mean velocity,

V = 2.36 feet per second; hydraulic mean radius, R = 2.31; wetted perimeter, 191 feet; n = 0.027; C, in Chezy's formula, 62.58; the discharge, D, was 1,046 second-feet.

At Collinston, Utah, the bed of Bear River consists of cobble rock stones and bowlders. The fall was found to be, S = 0.00131; A = 427 square feet; V = 2.333 feet per second; R = 1.58; wetted perimeter, 270; n = 0.029; C, in Chezy's formula, 51.28; the discharge, 996 second-feet.

ESTIMATION OF DISCHARGES AT MILLDAMS.

On rivers which, like those in New England, have been used for water power, it is often difficult to find a section where measurements with the current meter can be readily made. The milldams placed at short intervals back up water or introduce conditions unfavorable to direct measurement of flow. On the other hand, the facilities at the milldams are often excellent for noting the height of water, as gages are frequently maintained in the interest of the mill owners. In a number of cases where controversies have arisen concerning water power or there now exist contracts for the division of the available flow, elaborate computations have been made showing the discharge over the dams and through the various openings leading to the mill wheels. Occasionally these computations of flow are sufficiently extensive to have general interest in showing the run-off from a given drainage area, but more often the results are fragmentary.

Probably the earliest and most thorough determination of the flow of a river by estimating the amount taken by mills and passing over the dam is that begun by Mr. J. B. Francis over a half century ago on the Merrimac River at Lawrence, Massachusetts. This may be considered as the model of all attempts of this kind. Similar computations, based upon the Francis formula, have been made on other New England streams, notably on Connecticut River at Holyoke, Massachusetts, and on Kennebec River at Waterville, Maine. The uncertainty as to the application of certain constants or factors is such that estimates of this kind are apt to be misleading unless made by an engineer thoroughly familiar not only with the fundamental data, but with all of the varying local conditions. In order to make computations of daily discharge and correction for changes in the conduits diverting water above the dam, it is necessary to maintain records of various facts besides the height of water. To facilitate the keeping of such records blanks have usually been prepared with a space for entering the depth of water on the crest of the dam, and the length of this in linear feet—especially when modified from day to day by the use of flashboards. These records of depth are usually made night and morning, and occasionally are noted every two or three hours throughout the day. Besides these, spaces are provided for reading the height of water at the headrace and tailrace of each mill, giving data for the working head on the water wheels. The number of

wheels, the size and kind, the number of hours operated, and other facts concerning their use are also given, in order to compute the probable flow through each wheel and add this to the amount passing over the dam. Corrections must usually be introduced for leakage and for the amount escaping through waste ways. It is evident that for any given locality with a number of mills the recording of the facts not only requires care and time, but some display of intelligence on the part of the workmen, to whom the recording is necessarily intrusted.

All of the conditions above noted, and the uncertainty regarding accuracy of the constants used in the computations, tend to make the estimates not only complicated, but introduce more or less doubt as to the value of the results. This is particularly true when there are a number of mills taking water from the impounded river and in seasons of low water when the greater proportion passes through the mill wheels. At a number of localities where such estimates are made all of the water enters the mill races during the summer, leaving the crest of the dam dry.

Estimates of the flow of streams at milldams have been recently extended to certain streams in New York, most of which are tributary to Mohawk River. These were begun in October, 1898, by Mr. George W. Rafter, who was at that time employed on special water-supply investigations for the United States Board of Engineers on Deep Waterways. This board, consisting of three engineers designated by the President, one from the Engineer Corps of the United States Army, one from the Coast and Geodetic Survey, and one from civil life, was authorized by act of Congress approved June 4, 1897 (30 Stat. L., 50). Its purpose is to make surveys and examinations, including estimates of cost of deep waterways between the Great Lakes and the Atlantic tide waters, as recommended by the report of the Deep Waterways Commission, transmitted to Congress on January 18, 1897.[1] The work of the board was continued by the act of July 1, 1898 (30 Stat. L., 636), providing that estimates should be prepared for cost of waterways 21 and 30 feet in depth, and by act of March 3, 1899 (30 Stat L., 1109).

Under the direction of Mr. Rafter about 20 stations for studying sources of supply for deep waterways have been established in the State of New York, the locations of which are shown by fig. 12, on page 79 of Part IV of the Twentieth Annual Report of the Geological Survey.

In each case these points of measurement are at dams built to furnish power for mills, or constructed by the State for supplying water to the Erie Canal and its feeders. The dams thus employed as weirs are of various sections and materials. A few are of stone, solidly built, but most are of timber. Some of the latter are tight, while others

[1] Report of the United States Deep Waterways Commission, prepared at Detroit, Michigan, December 18–22, 1896, House Doc. No. 192, Fifty-fourth Congress, second session.

leak, and in these cases estimates have been made of the quantity flowing through the dam. Usually the estimate was made at the establishment of the river station, and leakage was considered as being constant. In a few instances current-meter measurements were made of the leakage, and the quantity found was used as a correction in the computations.

In examining the dams in the rivers it was found that many of them were irregular in longitudinal profile of crest. In a number of cases they were so repaired as to give a horizontal crest, but at several localities it was impossible to eliminate this irregularity. In these cases a careful profile of the crest was plotted and divided into parts in such a way that the crest of each portion could be considered as horizontal without introducing serious errors. Computations were then made of the flow through each section irrespective of its neighbor, and the quantities in all sections were added together to give the total flow over the dam. These computations were made for different heights of water and plotted graphically with the head on the crest in feet as ordinates and the discharge in second-feet as abscissas. A smooth curve was then drawn through these points, from which discharges have been read for various heads. In a number of instances these curves have been revised, using coefficients determined at a later time.

In order to compute the discharge over dams, it is necessary to make certain assumptions or employ coefficients obtained by experiment. The coefficients for determining the flow over broad-crested weirs are somewhat uncertain, especially with high heads. The most reliable coefficients are those determined by experiments of Bazin's, published in the Annales des Ponts et Chaussées.[1] In those experiments the head on the crest of the weir never exceeded $1\frac{1}{2}$ feet. As the coefficients over broad-crested weirs vary considerably with the head, it is a matter of judgment what coefficients to apply when the heights exceed those experimented upon by Bazin. Profiles of the dams as constructed in the river seldom correspond exactly with the profile for which the coefficients were determined. For each case it is necessary to assume an experimental profile which corresponds most closely with the measuring dam. In order to eliminate these two sources of error, experiments were instituted at Cornell University to determine coefficients for experimental flat-crested weirs as used by Bazin with heads on crest as high as 6 feet, and also upon other forms of weirs corresponding to those of the dams over which measurements are made.[2]

In making these experiments the first question that arose was to determine the actual quantity of water flowing over the experimental

[1] Annales des Ponts et Chaussées, Ire partie, 1898, 2e Trimestre, No. 24, p. 151 to 264. Expériences Nouvelles sur l'Écoulement en Déversoir (6e article), par M. H. Bazin, Inspecteur général des Ponts et Chaussées.

[2] On flow of water over dams, by George W. Rafter: Proc. Am. Soc. Civ. Eng., March, 1900, Vol. XXVI, No. 3, pp. 226-319.

weirs. To determine this a sharp-crested weir was constructed of exactly the same dimensions as that experimented upon by Bazin, for which he (Bazin) has published accurate coefficients. Bazin's coefficients for this sharp-crested weir were determined only for small heads.

In order to obtain accurate coefficients for sharp-crested weirs for a greater head, another weir of shorter length was placed below the Bazin weir in the same flume. Knowing the actual quantity flowing over the Bazin weir, and carrying the height on crest to the limit of the Bazin experiments, it was possible to determine coefficients for sharp-crested weirs for heads as high as about 6 feet. The coefficients determined from this second sharp-crested weir were then used to find the actual quantity of water flowing over all experimental sections used thereafter. Gates were so arranged that the quantity of water flowing in the flumes could be varied at will, and starting with a high head the water was gradually reduced in quantity, reducing thereby the head on the crest to zero. The gates were allowed to remain in each of the eight or ten positions from ten minutes to an hour, so that the flow for that interval was constant. By reading the head of the sharp-crested weir, the water flowing at the given width of gate opening could be determined. At the same time the head on the experimental weir was read and, noting the quantity, the coefficients computed for use in the formula $q = CLH^{\frac{3}{2}}$. In this formula $C = m\sqrt{2g}$ of Bazin's formula. One run was made for each experimental weir, and eight or ten points of the curve were determined. The experimental weir, which was constructed of wood, was then torn out and one of another section put in its place. When all worked well it required one day for experimentation on each section. Experiments were made on forms of weirs corresponding to nearly all of the dams over which the flow was measured.[1]

Practically all the computations of the flow of streams made by the Board on Deep Waterways had been completed before these coefficients for high heads were determined, so that Bazin's coefficients were used instead of the Cornell coefficients, although in Mr. Rafter's opinion the Cornell coefficients would be more accurate. It was proposed to recompute back records, using the Cornell coefficients, but lack of time and funds have prevented. The monthly totals have, however, been approximately corrected. There are some discrepancies between Bazin's and the Cornell coefficients, even for low heads, which are attributed to difference in the construction of the experimental weirs and the consequent action of the air cushion. It is possible that the conditions in the Cornell experiments are nearer those in actual dams.

As has been stated, most of the measuring stations are dams furnishing power for mills, and of course a large quantity of water passes

[1] On flow of water over dams, by George W. Rafter: Proc. Am. Soc. Civ. Eng., March, 1900, Vol. XXVI, No. 3, pp. 228-319.

through the mill race and wheels and not over the dam. In order to determine this quantity of water, gages are used, as before noted, above the wheels in the headrace and below the wheels in the tailrace, so that by simultaneous readings the head on the wheels at any time may be determined. The size and type of wheels used in each mill and the dimension of the gates were ascertained. In many cases, especially in the case of new wheels, records of careful ratings made at Holyoke, Massachusetts, were obtained for the particular wheels installed in the mills. Where these could be obtained they were used to determine the flow through the wheels. In other cases it was necessary to rely upon the figures published in the trade catalogues for the quantity of water flowing through the various wheels at the various heads, although these quantities are not always accurate. In some of the headraces there are overflows which must be taken into account as the head increases, and over which the flow is somewhat uncertain. When the State dams were used, as in most cases, in New York the flow through the canal feeders was measured once and assumed to be constant thereafter.

The following table gives a list of the New York streams, the flow of which has been computed as described above. Their drainage areas are also given. The numbers in the first column are those shown in the Twentieth Annual Report, Part IV, fig. 12, where the location of the points of observation is given.

Streams measured by the United States Board of Engineers on Deep Waterways.

No.	Streams.	Locality.	Drainage area.
			Sq. miles.
1	Seneca River	Baldwinsville	3,103
2	Oswego River	Fulton	4,916
3	Chittenango Creek	Bridgeport	307
4	Oneida Creek	Kenwood	59
5	Wood Creek	Near mouth	
6	Fish Creek, west branch	McConnellsville	187
7	Fish Creek, east branch	Above Point Rock	104
8	Salmon River	About 1 mile above falls	191
9	Mohawk River	Ridge Mills	153
10	Ninemile Creek	1 mile below Stittville	68
11	Oriskany Creek	State Dam, Oriskany	144
12	do	Coleman	141
13	Sauquoit Creek	New York Mills	52
14	West Canada Creek	Middleville	519
15	Mohawk River	Little Falls	1,306
16	East Canada Creek	Dolgeville	256
17	Garoga Creek	3 miles above the Mohawk	81
18	Cayadutta Creek	Below Johnstown	40
19	Schoharie Creek	State Dam, Fort Hunter	947
20	Mohawk River	State Dam, Rexford Flats	3,385
21	Hudson River	Mechanicville	4,500
22	do	Fort Edward	
23	Schroon River	Warrensburg	563
24	Black River	Watertown	1,389

The results obtained at the localities named above, from September, 1898, to May, 1899, inclusive, as computed by Mr. George W. Rafter, are given in the following table. The numbers in the first column of the preceding table refer to the same numbers in this table:

Estimated monthly discharge of various New York rivers in cubic feet per second.

No.	1898.				1899.				
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.
1	.....	.....	3,137	2,689	2,851	1,769	3,875	4,543	2,568
2	.....	.....	6,220	5,300	6,150	4,075	7,880	11,000	6,586
3	129	320	550	530	600	450	711	820	230
4	.....	76	95	75	97	79	126	160	58
5	.....	.....	.....	.....	.....	.....	.....	.....	.....
6	108	300	340	180	385	170	530	1,040	215
7	250	310	380	201	209	251	342	751	295
8	.....	.....	490	315	522	200	468	2,220	605
9	.....	324	356	216	382	199	422	952	275
10	398	98	92	135	225	85	210	340	47
11	.....	325	327	327	295	291	342	466	119
12	.....	.....	.....	.....	.....	.....	.....	.....	.....
13	27	56	57	57	58	58	111	127	38
14	.....	1,071	1,125	922	1,028	1,422	1,058	3,365	1,456
15	2,378	2,493	2,891	2,036	2,753	1,510	3,757	8,102	2,651
16	638	581	689	564	816	439	519	1,978	633
17	.....	140	190	77	43	47	160	500	99
18	16	64	91	44	39	31	74	251	31
19	409	1,422	2,447	1,853	2,584	2,224	4,072	4,380	858
20	.....	.....	.....	4,550	5,850	4,000	9,250	17,400	4,150
21	3,872	7,895	9,243	5,436	6,668	5,258	9,618	23,645	9,752
22	.....	.....	.....	.....	.....	.....	.....	.....	.....
23	166	263	464	783	606	478	564	2,877	3,150
24	1,744	3,607	4,510	2,752	4,704	2,381	5,112	14,172	5,940

TURBIDITY.

Many attempts have been made to determine the amount of silt carried by water in suspension, but as a rule these necessitate elaborate operations of filtering, drying, and weighing. One of the most convenient methods for field work is that recently applied by Mr. Allen Hazen, who has prepared an arbitrary scale dependent upon the degree of opacity of the water. Observations of turbidity are taken by putting a stick into the water under examination and noting the distance beneath the surface at which a given object—usually a small wire—can be seen. The turbidity is then read from a scale graduated on this stick. This is most conveniently accomplished by having a second or smaller stick placed in front of the first, the end of which is brought to the water line at a point where the wire can just be seen. Upon removing the two together the position of the smaller stick on the scale gives the turbidity.

Observations are taken in the open air, as too high results are obtained under a roof, even with good light. They preferably should be made in the middle of the day, and not in direct sunlight. In case the sun is shining the observer can stand so that his shadow covers the water immediately above the stick and wire. The observer stands erect with his feet a little above the water, although some variation in this respect does not materially influence the results.

The stick should be about 5 feet long and five-eighths of an inch square. A platinum wire should be inserted at a point about 1 inch from the end at rightangles and projecting 1 inch. This wire should be about 0.04 inch in diameter. The stick is then graduated, the figures being inversely proportional to the distances from the wire, 1.00 coming at 1 inch. The following table gives the graduations up to 50 inches:

Scale of turbidity.

Turbidity.	Inches.	Turbidity.	Inches.	Turbidity.	Inches.
2.00	0.50	0.10	10.00	0.05	20.00
1.50	.66	.09	11.11	.04	25.00
1.20	.83	.08	12.50	.03	33.30
1.00	1.00	.07	14.30	.02	50.00
.50	2.00	.06	16.70	.01	100.00

MEASUREMENTS AT RIVER STATIONS.

KENNEBEC RIVER AT WATERVILLE, MAINE.

This river has been described by Prof. Dwight Porter in the Nineteenth Annual Report, Part IV, pages 65 to 84, the general location of the stream being shown on Plate IX. Computations of discharge at Waterville, Maine, were made by Mr. Sumner Hollingsworth from about 1892 to the time of his death, which occurred June 27, 1899. Additional figures have been furnished by Mr. James L. Dean, engineer of the Hollingsworth & Whitney Company, a slightly different system of computation being employed by Mr. Dean, as it has been impracticable to introduce the corrections made by Mr. Hollingsworth, the principles upon which he worked not being fully recorded. Corrections were probably made for loss of head in the tailrace and leakage. The figures of daily discharge from 1892 to August 31, 1898, as computed by Mr. Sumner Hollingsworth, are given in Water-Supply Paper No. 27, page 14; those subsequent to the above date have been furnished by Mr. Dean.

Concerning those for 1899, Mr. Dean states that the figures subsequent to May 1 have not been computed with the same care as previous records, but they are believed to be correct for most practical purposes. The discharge over the dam was computed as usual, but that from the wheels was not estimated separately for each day, using the head of each wheel, and the speed of rotation, as heretofore done. Instead of this the average performance was taken. A comparison of gage readings and water discharges shows little connection, as flashboards are used on the dam. The Sunday flow is also irregular, as the mill at Waterville is sometimes operated Saturday night, drawing the water from the pond, so that there is no flow except leakage on Sunday. During the season of low water there is usually less passing on Sunday than on week days, as at many mills on the river the dams are closed in order to fill the ponds.

Daily discharge in second-feet of Kennebec River at Waterville, Maine.

1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2,475	2,539	4,170	20,385	36,048	14,341	4,385	3,790	2,477	2,691	6,382	3,752
2	2,284	2,955	4,188	16,556	39,372	13,776	4,343	2,707	2,489	2,862	5,182	3,740
3	2,222	2,687	5,648	13,871	38,301	10,900	3,440	2,887	2,453	2,180	4,691	3,667
4	2,715	3,090	5,163	12,143	37,358	8,791	3,490	2,833	1,437	1,831	4,115	1,747
5	2,771	2,775	2,997	10,830	37,730	9,846	4,343	2,809	2,510	1,865	3,467	3,538
6	3,431	3,068	4,094	10,150	37,569	10,301	4,272	3,712	2,362	2,119	3,231	3,227
7	1,807	3,475	5,070	7,080	31,580	9,189	4,477	3,252	3,093	1,570	3,880	3,221
8	4,826	2,994	5,033	6,563	29,880	9,098	4,203	4,374	3,073	1,299	3,675	3,362
9	5,434	3,744	4,767	7,472	28,753	12,541	5,464	4,218	3,018	1,150	4,133	2,995
10	4,492	3,154	4,623	10,457	25,636	14,318	1,745	4,017	3,042	961	3,351	2,635
11	3,025	3,829	5,329	15,299	22,059	12,086	4,111	3,048	3,050	1,585	5,332	1,782
12	3,286	3,317	6,752	19,848	21,899	11,322	4,484	3,413	3,057	1,731	5,856	3,208
13	3,240	3,680	8,397	44,854	24,042	11,003	4,267	2,927	2,505	1,585	4,896	2,326
14	3,287	3,912	9,880	47,141	34,332	10,777	3,776	1,130	1,913	1,288	3,332	1,873
15	4,909	4,026	11,534	50,381	32,988	12,514	4,327	3,443	1,480	1,299	3,465	1,888
16	3,717	4,042	12,816	49,415	27,500	11,295	3,994	2,499	1,560	3,365	3,264	1,883
17	3,891	3,764	12,215	47,112	24,756	10,584	3,611	2,560	1,530	6,031	3,490	2,160
18	3,453	3,221	11,918	47,321	23,440	9,478	3,896	2,491	1,570	5,055	3,698	1,723
19	3,460	3,267	12,484	44,700	23,153	9,196	3,938	2,622	1,607	4,454	5,018	2,315
20	3,505	2,885	13,218	39,327	20,592	11,129	3,747	2,528	1,876	3,264	8,798	2,447
21	3,893	3,172	14,580	36,671	19,088	10,855	3,835	913	2,223	2,872	8,935	2,560
22	4,614	3,764	17,177	33,789	18,570	9,950	5,038	3,425	1,851	2,690	8,046	2,374
23	2,542	2,133	16,615	30,792	17,073	8,334	3,871	2,866	1,888	6,036	7,184	2,779
24	2,321	3,437	15,987	34,352	15,277	9,483	3,418	3,425	1,916	6,318	6,007	3,013
25	2,866	4,352	17,812	52,119	15,993	8,864	3,747	2,849	3,689	4,924	7,811	2,489
26	2,032	3,933	17,029	45,520	15,589	7,508	3,879	4,432	5,443	4,288	7,923	2,471
27	3,136	3,653	16,560	38,083	15,639	5,267	3,385	4,218	4,788	6,514	10,037	2,761
28	2,905	4,387	18,928	37,354	14,611	4,326	4,189	3,940	3,581	15,319	3,672	2,464
29	2,727	.....	19,762	33,652	16,632	5,689	3,444	3,396	3,778	11,127	2,758	2,499
30	1,738	.....	17,711	31,767	16,962	6,715	3,204	3,555	3,247	9,229	3,723	2,067
31	2,007	.....	27,432	.....	16,298	.....	2,832	2,857	.....	7,672	.....	2,178
Mean.	3,213	3,402	11,287	29,833	25,120	9,983	3,908	3,133	2,618	4,047	5,178	2,620

1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2,529	2,458	3,362	6,343	41,348	13,992	6,386	4,020	1,985	1,200	1,405	1,405
2	2,202	2,198	3,047	6,114	39,433	12,783	4,924	3,800	1,985	1,297	2,759	1,405
3	2,274	2,187	3,333	6,080	36,354	10,632	5,164	4,380	1,403	1,445	4,025	1,000
4	2,159	2,163	3,324	5,945	36,864	11,573	3,478	4,088	1,695	1,269	4,025	2,855
5	2,452	1,580	1,960	6,125	30,725	12,183	5,089	4,380	1,985	1,823	1,636	3,476
6	2,451	2,509	3,331	6,135	30,358	11,076	4,943	2,865	1,695	1,303	3,258	3,040
7	2,449	2,173	3,563	6,343	30,025	10,516	5,264	4,088	1,985	1,330	3,039	1,950
8	1,739	2,071	3,516	6,859	29,257	11,679	5,164	4,088	1,985	800	2,565	1,985
9	2,757	2,057	3,502	7,441	26,688	12,450	3,836	4,244	2,275	1,069	2,275	1,695
10	2,519	2,152	3,428	8,904	24,760	12,450	4,943	4,244	1,646	755	2,058	900
11	2,400	2,141	3,357	9,472	22,244	10,638	4,943	4,013	2,275	561	1,695	1,405
12	2,386	2,244	2,302	9,272	20,182	10,213	4,832	4,013	1,985	1,564	1,200	1,105
13	2,404	2,348	3,353	10,999	18,665	6,024	4,943	3,880	1,985	1,822	1,478	1,985
14	2,436	1,964	3,423	19,504	19,543	7,008	5,738	2,420	1,985	1,245	1,985	4,888
15	1,678	1,844	3,624	22,940	14,849	6,693	4,943	3,880	1,985	924	1,985	4,501
16	2,731	2,392	3,773	37,830	14,944	7,432	4,943	3,400	1,985	1,405	1,985	4,608
17	2,439	2,434	3,501	30,458	17,275	5,881	4,832	3,400	1,695	1,695	1,768	2,400
18	2,631	2,727	3,253	30,190	15,044	6,707	5,180	3,500	1,405	1,405	1,695	2,638
19	2,434	2,198	1,960	36,964	15,044	7,274	5,180	2,560	1,985	1,115	1,100	1,985
20	2,628	2,915	3,320	41,348	15,597	6,453	4,832	1,670	2,275	1,405	1,405	2,565
21	2,440	2,734	3,080	34,305	16,162	7,006	5,424	2,634	2,275	1,115	2,275	2,275
22	2,094	2,744	2,778	30,090	18,296	7,237	6,210	3,220	2,565	1,118	1,695	2,275
23	2,709	2,451	2,711	38,466	17,275	7,237	5,588	2,840	2,275	1,405	2,058	2,265
24	2,154	2,745	2,837	45,172	15,872	9,432	6,368	2,534	1,500	1,400	1,985	1,900
25	2,435	2,929	2,770	41,348	15,791	5,593	5,785	2,180	1,885	1,105	1,985	1,900
26	2,450	1,420	2,030	42,736	11,380	7,274	5,785	2,158	1,615	1,115	1,405	2,275
27	2,454	3,039	2,786	45,422	12,539	7,237	5,424	1,620	1,320	1,115	1,695	2,275
28	2,434	3,362	2,740	39,533	12,203	6,849	5,785	2,120	2,104	1,115	1,695	1,695
29	1,245	.....	2,998	41,248	13,027	7,006	4,088	2,560	2,116	1,000	1,100	1,405
30	2,513	.....	3,962	29,200	13,535	6,386	2,400	2,100	2,100	1,115	1,405	1,405
31	2,453	.....	6,820	.....	12,783	.....	4,020	2,380	.....	1,115	.....	.....
Mean	2,357	2,364	3,218	23,429	21,228	8,807	5,036	3,217	1,906	1,224	2,02	2,254

ANDROSCOGGIN RIVER AT RUMFORD FALLS, MAINE.

This river receives the drainage from the Rangeley and other lakes, near the border line between Maine and New Hampshire. It flows in a general southerly and southeasterly direction, descending with rapid fall and furnishing considerable power. It is described by Prof. Dwight Porter in the Nineteenth Annual Report, Part IV, pages 84 to 97. The discharge at Rumford Falls since 1892 has been ascertained by Mr. Charles A. Mixer, resident engineer of the Rumford Falls Power Company. Figures of daily discharge up to the end of December, 1895, have been printed in Water-Supply Paper No. 27, pages 11 to 14. The table is continued for the years 1896 to 1898 in the Twentieth Annual Report, Part IV, pages 67 to 69. These figures are obtained by adding the actual measured quantities passing through the wheels and the computed flow over the dam, using the customary Francis weir formula.

Mr. Mixer has prepared a table giving the departure of the precipitation of 1899 from the normal, which is taken at 43.41 inches, showing that for this latter year there was only 31.58 inches, or a deficiency of 27 per cent. This emphasizes the importance of water storage, not only for such rare periods, but also for equalizing the fluctuations from month to month during every year. The lowest monthly run-off, 0.71 inch in depth, was in August, the month of greatest evaporation. At this time the run-off was 0.07 inch more than the precipitation. The lowest daily discharge for the year, 1,124 second-feet, was 0.48 second-foot per square mile. The total annual run-off averages 53 per cent of the total precipitation as measured at Rumford Falls; but in 1899 the percentage rose to 59, the increase presumably being due to storage. The records of precipitation have not been kept for a sufficiently long period to give a wide range in fluctuation, but, judging from the effect on the wells, there has been no such period of drought for from fifty to seventy-five years.

Comparison of rainfall at Rumford Falls, Maine.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Normal	3.23	4.28	3.55	2.99	3.92	3.63	4.48	3.49	3.34	2.78	4.74	2.98
1899	3.18	2.56	5.89	1.50	1.59	2.27	4.71	.64	3.00	2.05	1.94	1.95
Normal accumulation	3.23	7.51	11.06	14.05	17.97	21.60	26.08	29.57	32.91	35.69	40.43	43.41
1899 accumulation	3.18	5.74	11.63	13.13	15.02	17.29	22.00	22.64	25.64	27.69	29.63	31.58
Accumulated excess	.....	.....	.57	.....	.....	.....	.....	.....	.....	.....	.....	.....
Accumulated deficiency	.05	1.77	.....	.88	2.95	4.31	4.08	6.93	7.27	8.00	10.80	11.83

Daily discharge in second-feet of Androscoggin River at Rumford Falls, Maine, for 1899.

[Drainage area, 2,320 square miles.]

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2,398	1,832	1,926	2,029	24,057	3,773	3,224	1,521	1,359	2,130	2,186	1,230
2	2,441	1,861	1,955	2,088	24,077	3,495	3,600	1,557	1,453	1,784	3,172	1,247
3	1,933	1,736	1,877	1,998	21,468	3,383	2,800	1,492	1,247	1,709	2,865	1,700
4	2,124	1,825	1,791	1,974	19,480	3,400	1,700	1,601	1,455	1,532	2,232	1,792
5	2,255	1,810	1,738	2,024	16,631	3,042	1,510	1,758	1,466	1,566	2,030	1,299
6	2,613	1,789	1,780	2,009	15,111	2,988	1,485	1,717	1,469	1,454	1,825	1,170
7	2,675	1,768	1,978	2,129	14,368	3,574	1,718	1,636	1,494	1,527	2,060	1,290
8	2,275	1,773	2,017	2,436	14,358	3,625	1,823	1,325	1,332	1,330	1,899	1,018
9	2,267	1,619	1,801	2,460	13,970	3,264	1,900	1,442	1,328	1,368	1,843	1,016
10	2,192	1,600	1,712	2,688	12,874	3,295	1,779	1,274	1,141	1,400	1,778	1,010
11	2,074	1,462	1,706	2,954	12,035	3,761	1,934	1,336	1,281	1,482	1,674	1,084
12	1,931	1,812	1,754	3,147	11,182	3,150	1,589	1,357	1,357	1,351	1,230	1,253
13	2,316	1,814	1,646	2,975	10,721	2,984	2,366	1,317	1,319	1,231	1,170	5,274
14	2,059	1,957	2,037	3,054	10,054	3,012	1,818	1,261	1,368	1,452	1,171	3,354
15	2,084	1,981	2,007	4,236	9,122	2,797	1,494	1,209	1,529	1,230	1,516	1,965
16	2,127	1,929	1,913	6,808	7,630	3,494	1,651	1,250	1,274	1,234	1,476	1,635
17	2,135	1,919	1,846	6,490	7,134	3,524	1,250	1,221	1,243	1,413	1,561	1,183
18	2,137	1,920	1,843	7,457	5,960	3,220	1,232	1,326	1,300	1,432	1,343	1,331
19	2,325	1,886	1,834	9,509	5,340	3,186	1,563	1,455	1,470	1,405	1,300	1,781
20	1,924	1,824	1,826	11,127	5,706	3,079	1,178	1,453	1,524	2,096	1,489	1,795
21	1,848	1,899	1,819	11,543	6,497	3,024	1,271	1,349	1,788	1,744	1,860	2,051
22	1,835	1,960	1,823	12,461	6,028	3,529	2,433	1,331	2,043	1,500	1,914	1,929
23	2,093	2,029	1,818	14,599	5,369	3,198	3,682	1,676	2,202	1,368	1,866	1,805
24	2,058	2,111	1,816	17,372	4,821	3,049	1,927	1,462	1,794	1,347	1,825	1,412
25	2,003	1,928	1,818	17,371	4,443	3,060	1,634	1,571	1,124	1,455	1,628	1,298
26	2,106	1,819	1,862	20,017	4,328	2,793	1,490	1,557	1,381	1,443	1,500	1,689
27	1,944	1,816	1,763	23,287	4,019	3,127	1,443	1,265	2,971	1,637	1,370	1,343
28	2,098	1,931	1,831	20,787	4,151	2,717	1,233	1,329	2,397	1,511	1,571	1,278
29	1,697	.....	1,839	21,319	4,465	3,297	1,142	1,382	2,223	2,767	1,382	1,097
30	1,760	.....	1,948	22,920	4,290	3,282	1,170	1,464	2,124	2,548	1,224	1,048
31	1,721	.....	1,976	.....	3,849	.....	1,267	1,372	.....	2,220	.....	1,437
Mean	2,111	1,843	1,848	8,709	10,114	3,238	1,817	1,428	1,580	1,604	1,733	1,606

COBBOSSEECONTEE RIVER AT RESERVOIR DAM NEAR AUGUSTA, MAINE.

This stream receives the overflow from a group of lakes lying from 5 to 15 miles westerly from Augusta, Maine, and empties into Kennebec River 8 miles below that city. It is described by Prof. Dwight Porter in the Nineteenth Annual Report, Part IV, page 79. A record of the water passing the upper dam on this stream has been furnished by Mr. Alexander H. Twombly, engineer of the Forest Paper Company, Yarmouthville, Maine. At the reservoir dam are gates by which the supply of water for the mill is regulated, and there is also a water wheel which operates a pumping station. When this wheel is in operation the regulating gates are shut down enough to deliver a constant supply of water to the mill, as shown by the tables on page 29. The great Cobbosseecontee dam furnishes a supplemental supply to this reservoir and water is occasionally drawn from it. At the point of measurement the water is shut back entirely on Sundays and holidays, as shown by the table. In the tables the reference "Gates up; all that flows" covers the period when there was no means of ascertaining the discharge, it being less than 220 second-feet and from that as low as 120 second-feet, diminishing probably at a constant rate. After November 1, 1899, the discharge, however small, can be measured.

Daily discharge in second-feet of Cobbosseecontee River, at the upper dam, near Augusta, Maine.

[Drainage area, 230 square miles.]

1890.

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	300	290	290	290	393	300
2	.....	300	290	290	290	379	300
3	.....	300	.....	290	290	379	300
4	.....	.....	290	290	290	379	300
5	.....	306	290	290	.....	368	300
6	.....	326	290	290	290	357	300
7	.....	356	290	.....	290	347	.....
8	.....	374	290	290	300	347	300
9	.....	374	290	290	300	333	300
10	.....	340	.....	290	300	333	300
11	.....	314	290	290	300	326	300
12	.....	306	290	290	.....	300	300
13	.....	156	290	290	300	300	300
14	.....	300	290	.....	300	300	.....
15	.....	300	290	290	300	300	300
16	340	300	290	290	300	.....	300
17	356	300	.....	290	300	300	300
18	356	.....	290	290	300	379	300
19	356	.....	290	290	.....	445	300
20	340	290	290	290	300	431	300
21	326	290	290	290	300	418	.....
22	.....	290	290	290	300	405	300
23	300	290	290	290	300	393	300
24	300	290	34	290	337	379	300
25	306	290	290	290	337	368	.....
26	314	290	290	290	337	357	290
27	314	.....	280	290	345	347	290
28	306	290	290	.....	345	337	.....
29	.....	290	290	290	345	337	290
30	300	290	290	290	379	300	290
31	.....	290	.....	.....	393	.....	290
Mean	324	307	290	290	313	356	298

1891.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	290	850	839	2,169	300	300	300	290	285	260	(a)	(a)
2	290	780	774	2,114	300	300	300	.....	285	260	(a)	(a)
3	290	713	713	2,059	.....	300	300	285	280	260	(a)	(a)
4	.....	713	653	2,059	300	300	.....	285	280	.....	(a)	(a)
5	290	682	594	2,059	300	300	.....	285	280	260	(a)	(a)
6	290	620	567	1,940	300	300	300	285	.....	250	(a)	220
7	290	590	540	1,836	300	.....	300	260	280	250	(a)	220
8	290	.....	540	1,732	300	300	300	290	280	250	(a)	220
9	290	373	515	1,598	300	300	300	.....	280	250	(a)	220
10	290	435	540	1,567	.....	300	300	285	280	250	(a)	(a)
11	.....	458	743	1,495	300	300	300	285	280	.....	(a)	(a)
12	300	458	807	1,514	300	300	.....	285	270	250	(a)	(a)
13	300	458	807	1,514	300	300	290	285	.....	250	(a)	(b)
14	300	548	1,801	1,365	300	.....	290	285	270	250	(a)	(a)
15	300	529	1,753	1,223	300	300	290	285	270	250	(a)	(a)
16	300	590	1,573	1,270	300	300	290	.....	270	250	(a)	(a)
17	300	602	1,364	1,318	.....	300	290	285	270	250	(a)	(a)
18	300	574	1,286	1,318	300	300	290	285	270	.....	(a)	(a)
19	300	516	1,241	1,318	300	300	.....	285	270	220	(a)	(a)
20	300	516	1,204	1,318	306	300	290	285	.....	220	(a)	(b)
21	300	483	1,167	1,273	314	.....	290	285	270	220	(a)	(a)
22	300	483	1,531	1,050	316	300	290	285	270	220	(a)	(a)
23	503	363	2,199	1,013	300	300	290	.....	270	220	(a)	(a)
24	1,120	363	2,365	300	.....	300	290	285	260	220	(a)	220
25	1,100	393	2,365	300	300	300	290	285	260	.....	(a)	(b)
26	1,063	620	2,585	314	300	300	.....	285	260	220	(a)	(b)
27	1,063	942	2,531	306	300	300	290	285	.....	(a)	(a)	(b)
28	1,063	907	2,344	306	300	.....	290	285	260	(a)	(a)	220
29	1,063	.....	2,344	300	300	300	290	285	260	(a)	(a)	220
30	1,079	.....	2,344	300	300	300	290	.....	260	(a)	(a)	220
31	1,001	.....	2,295	.....	.....	.....	290	285	.....	(a)	.....	220
Mean	516	576	1,385	1,277	301	300	293	286	272	242	.....	.....

a Water so low only gage record kept.
b Water shut back Sundays and holidays.

Daily discharge in second-feet of Cobbosseecontee River, at the upper dam, near Augusta, Maine—Continued.

1892.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	220	270	280	280	------	280	280	280	280	280	280	280
2	220	270	280	280	280	280	280	280	280	------	280	280
3	------	270	280	------	280	280	------	280	280	280	280	280
4	220	280	280	280	280	280	------	280	------	280	280	------
5	250	280	280	280	280	------	280	280	280	280	280	250
6	250	280	------	294	280	280	280	280	280	280	------	280
7	250	------	280	294	280	280	280	------	280	280	280	280
8	250	280	280	294	------	280	280	280	280	280	280	280
9	250	280	280	286	280	280	280	280	280	------	280	280
10	------	280	280	------	280	280	280	280	280	280	280	280
11	250	280	280	306	280	280	(a)	280	------	280	280	------
12	250	280	280	294	280	------	(a)	280	280	280	280	280
13	250	280	------	280	280	280	(a)	280	280	280	------	280
14	250	------	280	280	280	280	(a)	------	280	280	280	280
15	270	280	280	280	------	280	(a)	280	280	280	280	280
16	270	280	280	280	280	280	(a)	280	280	------	280	280
17	------	280	280	------	280	280	(a)	280	280	280	280	280
18	270	280	280	280	280	------	280	280	------	280	280	------
19	270	280	280	280	280	------	280	280	280	280	280	280
20	276	280	------	280	280	280	280	280	280	280	------	280
21	276	------	280	280	280	280	280	------	280	280	280	280
22	270	280	280	280	280	280	280	280	280	280	280	280
23	270	280	280	280	280	280	280	280	280	------	280	280
24	------	280	280	------	280	280	------	280	280	280	------	280
25	270	280	280	280	280	280	280	280	------	280	280	------
26	270	280	280	280	280	------	280	280	280	280	280	280
27	270	280	------	280	280	280	280	280	280	280	------	280
28	270	------	280	280	280	280	280	------	280	280	280	280
29	270	280	280	280	280	280	280	280	280	280	280	280
30	270	------	280	280	280	280	280	280	280	------	280	280
31	------	------	280	------	280	------	------	280	------	280	------	280
Mean	258	279	280	283	280	280	280	280	280	280	280	280

a Water shut back.

1893.

1	------	280	280	535	435	300	280	280	(a)	------	250	220
2	280	280	280	314	458	300	------	280	(a)	250	250	220
3	280	280	280	300	509	300	280	280	(a)	250	250	------
4	280	280	280	300	596	------	------	280	270	250	250	220
5	280	280	------	300	1,079	300	280	280	(a)	220	------	220
6	280	280	280	300	1,295	300	280	------	(a)	(a)	220	220
7	280	280	280	300	1,179	300	280	280	(a)	(a)	220	220
8	------	280	280	300	985	300	280	270	(a)	(a)	220	220
9	280	280	280	------	713	300	------	270	270	220	220	220
10	280	280	280	300	620	300	280	270	------	220	220	------
11	280	280	280	314	590	------	280	270	270	220	220	220
12	280	------	------	481	562	280	280	270	270	220	------	220
13	280	280	280	682	562	280	280	------	270	(a)	220	220
14	280	280	509	650	887	280	280	270	270	(a)	220	220
15	------	280	620	650	1,262	280	280	270	(a)	(a)	220	220
16	280	280	620	1,040	1,354	280	------	270	(a)	220	220	220
17	280	280	535	1,079	1,552	280	280	270	(a)	220	220	------
18	280	280	509	1,001	2,080	------	280	270	270	220	220	220
19	280	------	458	962	2,481	280	280	270	270	(a)	------	220
20	280	280	435	925	2,002	280	280	------	270	(a)	220	220
21	280	280	393	887	1,900	280	280	270	270	(a)	220	220
22	------	280	393	962	1,752	280	280	270	(a)	(a)	220	220
23	280	280	356	962	1,660	280	------	270	(a)	(a)	220	220
24	280	280	356	925	1,428	280	280	270	(a)	(a)	220	------
25	280	280	356	780	1,052	------	280	270	250	250	220	------
26	280	------	458	718	562	280	280	270	250	250	------	220
27	280	280	590	620	326	280	280	------	250	250	220	220
28	280	280	620	650	326	280	280	270	250	250	220	220
29	------	------	562	620	326	280	280	270	250	------	220	220
30	280	------	780	393	326	280	------	270	250	250	------	220
31	280	------	620	------	307	------	280	270	------	250	------	------
Mean	280	280	422	629	1,025	287	280	272	263	236	225	220

a Water shut back.

Daily discharge in second-feet of Cobbosseecontee River, at the upper dam, near Augusta, Maine—Continued.

1894.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	220	220	220	.....	300	925	.....	280	280	270	250	250
2	220	220	220	314	300	889	280	280	.....	250	250	.....
3	220	220	220	314	300	674	280	280	.....	250	250	250
4	220	.....	.....	306	280	326	.....	280	280	250	.....	250
5	220	220	220	306	280	326	280	.....	280	250	250	250
6	220	220	220	306	.....	326	280	280	280	250	250	250
7	.....	220	220	306	280	326	280	280	270	.....	250	250
8	220	220	220	26	280	326	.....	280	270	250	250	250
9	220	220	220	326	280	326	280	280	.....	250	250	.....
10	220	220	220	314	280	200	280	280	270	250	250	250
11	220	.....	.....	314	280	326	280	280	270	250	.....	250
12	220	220	276	314	280	314	280	.....	270	250	250	250
13	220	220	483	314	.....	300	280	280	270	250	250	250
14	.....	220	483	314	280	300	280	280	270	.....	250	250
15	220	220	426	.....	280	280	.....	280	270	250	250	250
16	220	220	426	430	280	280	280	280	.....	250	250	.....
17	220	220	410	430	280	.....	280	280	270	250	250	250
18	220	.....	405	430	280	280	280	280	270	250	.....	250
19	220	220	405	314	280	280	280	.....	270	250	250	250
20	220	220	630	314	.....	280	280	280	270	250	250	250
21	.....	220	900	314	280	280	280	280	270	.....	250	250
22	220	220	887	26	280	280	.....	280	270	250	250	250
23	220	220	692	326	280	280	280	280	.....	250	250	.....
24	220	220	306	314	280	.....	280	280	270	250	250	250
25	220	.....	14	314	280	280	280	280	270	250	.....	.....
26	220	220	314	306	336	280	280	.....	270	250	250	250
27	220	220	314	300	523	280	280	280	270	250	250	250
28	.....	220	314	300	499	280	280	280	270	.....	250	250
29	220	.....	300	.....	370	280	.....	280	270	250	.....	250
30	220	.....	300	300	523	280	280	280	.....	250	250	.....
31	220	.....	300	.....	862	.....	280	280	.....	250	.....	250
Mean	220	220	364	308	333	350	280	280	272	251	250	250

1895.

1	250	250	.....	250	385	280	280	280	.....	220	(a)	.....
2	250	250	.....	250	318	.....	280	280	270	220	(a)	220
3	250	.....	.....	250	300	280	280	280	270	220	.....	220
4	250	220	220	250	290	280	.....	.....	270	(a)	(a)	220
5	250	220	220	250	.....	280	280	280	270	(a)	(a)	220
6	.....	220	220	250	280	280	280	280	270	.....	(a)	220
7	250	220	220	14	280	280	.....	280	270	220	(a)	220
8	250	220	.....	343	280	280	280	280	.....	(a)	(a)	.....
9	250	220	220	733	280	.....	280	280	270	(a)	(a)	220
10	250	.....	.....	2,619	280	280	280	280	250	(a)	.....	220
11	250	220	220	1,301	280	280	280	.....	250	(a)	(a)	220
12	250	220	220	1,384	.....	280	280	270	250	(a)	(a)	220
13	.....	220	220	300	280	280	280	270	250	.....	(a)	220
14	250	220	220	74	280	280	.....	276	250	(a)	(a)	220
15	250	220	220	2,006	280	280	280	270	.....	(a)	(a)	.....
16	250	220	220	2,461	280	.....	280	270	250	(a)	(a)	220
17	250	.....	.....	1,698	280	280	280	270	250	(a)	.....	220
18	250	220	220	1,609	280	280	280	.....	250	(a)	220	220
19	250	220	220	1,400	.....	280	280	270	250	(a)	220	220
20	.....	220	220	1,271	280	280	280	270	(a)	.....	220	220
21	250	220	220	490	.....	280	.....	270	(a)	(a)	220	220
22	250	220	220	664	280	280	280	270	.....	(a)	220	.....
23	250	220	220	358	280	.....	280	270	220	(a)	220	220
24	250	.....	.....	385	280	280	280	270	220	(a)	.....	220
25	250	220	220	385	280	280	280	.....	220	(a)	220	.....
26	250	220	220	385	.....	280	280	270	220	(a)	220	250
27	.....	220	220	385	280	280	280	270	220	.....	220	250
28	250	.....	220	409	280	280	.....	270	220	(a)	.....	250
29	250	.....	220	409	280	280	280	270	.....	(a)	220	14
30	250	.....	220	409	280	.....	280	270	220	(a)	220	264
31	250	.....	.....	.....	260	.....	280	270	.....	(a)	.....	343
Mean	250	223	220	785	287	280	280	273	247	220	220	222

a Gates up; natural flow.

Daily discharge in second-feet of Cobbosseecontee River, at the upper dam, near Augusta, Maine—Continued.

1892.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	220	270	280	280	.....	280	280	280	280	280	280	280
2	220	270	280	280	280	280	280	280	280	.....	280	280
3	.....	270	280	.....	280	280	.....	280	280	280	280	280
4	220	280	280	280	280	280	.....	280	.....	280	280	.....
5	250	280	280	280	280	.....	280	280	280	280	280	250
6	250	280	.....	294	280	280	280	280	280	280	.....	280
7	250	.....	280	294	280	280	280	.....	280	280	280	280
8	250	280	280	294	.....	280	280	280	280	280	280	280
9	250	280	280	286	280	280	280	280	280	.....	280	280
10	.....	280	280	.....	280	280	280	280	28u	280	280	280
11	250	280	280	306	280	280	(a)	280	.....	280	280	.....
12	250	280	280	294	280	.....	(a)	280	280	280	280	280
13	250	280	.....	280	280	280	(a)	280	280	280	.....	280
14	250	.....	280	280	280	280	(a)	.....	280	280	280	280
15	270	280	280	280	.....	280	(a)	280	280	280	280	280
16	270	280	280	280	280	280	(a)	280	280	.....	280	280
17	.....	280	280	.....	280	280	(a)	280	280	280	280	280
18	270	280	280	280	280	.....	280	280	.....	280	280	.....
19	270	280	280	280	280	.....	280	280	280	280	280	280
20	276	280	.....	280	280	280	280	280	280	280	.....	280
21	276	.....	280	280	280	280	280	.....	280	280	280	280
22	270	280	280	280	280	280	280	280	280	280	280	280
23	270	280	280	280	280	280	280	280	280	.....	280	280
24	.....	280	280	.....	280	280	.....	280	280	280	.....	280
25	270	280	280	280	280	280	280	280	.....	280	280	.....
26	270	280	280	280	280	.....	280	280	280	280	280	280
27	270	280	.....	280	280	280	280	280	280	280	.....	280
28	270	.....	280	280	280	280	280	.....	280	280	280	280
29	270	280	280	280	280	280	280	280	280	280	280	280
30	270	.....	280	280	280	280	280	280	280	.....	280	280
31	.....	.....	280	.....	280	.....	.....	280	.....	280	.....	280
Mean	258	279	280	283	280	280	280	280	280	280	280	280

a Water shut back.

1893.

1	.....	280	280	535	435	300	280	280	(a)	.....	250	220
2	280	280	280	314	458	300	.....	280	(a)	250	250	220
3	280	280	280	300	509	300	280	280	(a)	250	250	.....
4	280	280	280	300	596	.....	.....	280	270	250	250	220
5	280	280	.....	300	1,079	300	280	280	(a)	220	.....	220
6	280	280	280	300	1,295	300	280	.....	(a)	(a)	220	220
7	280	280	280	300	1,179	300	280	280	(a)	(a)	220	220
8	.....	280	280	300	985	300	280	270	(a)	(a)	220	220
9	280	280	280	.....	713	300	.....	270	270	220	220	220
10	280	280	280	300	620	300	280	270	.....	220	220	.....
11	280	280	280	314	590	.....	280	270	270	220	220	220
12	280	.....	.....	481	562	280	280	270	270	220	.....	220
13	280	280	280	682	562	280	280	.....	270	(a)	220	220
14	280	280	509	650	887	280	280	270	270	(a)	220	220
15	.....	280	620	650	1,262	280	280	270	(a)	(a)	220	220
16	280	280	620	1,040	1,354	280	.....	270	(a)	220	220	220
17	280	280	535	1,079	1,552	280	280	270	(a)	220	220	.....
18	280	280	509	1,001	2,080	.....	280	270	270	220	220	220
19	280	.....	458	962	2,481	280	280	270	270	(a)	.....	220
20	280	280	435	925	2,002	280	280	.....	270	(a)	220	220
21	280	280	393	887	1,900	280	280	270	270	(a)	220	220
22	.....	280	393	962	1,752	280	280	270	(a)	(a)	220	220
23	280	280	356	962	1,660	280	.....	270	(a)	(a)	220	220
24	280	280	356	925	1,428	280	280	270	(a)	(a)	220	.....
25	280	280	356	780	1,052	.....	280	270	250	250	220	.....
26	280	.....	458	713	562	280	280	270	250	250	.....	220
27	280	280	590	620	326	280	280	.....	250	250	220	220
28	280	280	620	650	326	280	280	270	250	250	220	220
29	.....	.....	562	620	326	280	280	270	250	.....	220	220
30	280	.....	780	393	326	280	.....	270	250	250	.....	220
31	280	.....	620	.....	307	.....	280	270	.....	250	.....	.....
Mean	280	280	422	629	1,025	287	280	272	263	236	225	220

a Water shut back.

Daily discharge in second-feet of Cobbosseecontee River, at the upper dam, near Augusta, Maine—Continued.

1894.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	220	220	220	.....	300	925	.....	280	280	270	250	250
2	220	220	220	314	300	889	280	280	.....	250	250	.....
3	220	220	220	314	300	674	280	280	.....	250	250	250
4	220	.....	.....	306	280	326	.....	280	280	250	.....	250
5	220	220	220	306	280	326	280	.....	280	250	250	250
6	220	220	220	306	.....	326	280	280	280	250	250	250
7	.....	220	220	306	280	326	280	280	270	.....	250	250
8	220	220	220	26	280	326	.....	280	270	250	250	250
9	220	220	220	326	280	326	280	280	.....	250	250	.....
10	220	220	220	314	280	200	280	280	270	250	250	250
11	220	.....	.....	314	280	326	280	280	270	250	.....	250
12	220	220	276	314	280	314	280	.....	270	250	250	250
13	220	220	483	314	.....	300	280	280	270	250	250	250
14	.....	220	483	314	280	300	280	280	270	.....	250	250
15	220	220	426	.....	280	280	.....	280	270	250	250	250
16	220	220	426	430	280	280	280	280	.....	250	250	.....
17	220	220	410	430	280	.....	280	280	270	250	250	250
18	220	.....	405	430	280	280	280	280	270	250	.....	250
19	220	220	405	314	280	280	280	.....	270	250	250	250
20	220	220	630	314	.....	280	280	280	270	250	250	250
21	.....	220	900	314	280	280	280	280	270	.....	250	250
22	220	220	887	26	280	280	.....	280	270	250	250	250
23	220	220	692	326	280	280	280	280	.....	250	250	.....
24	220	220	306	314	280	.....	280	280	270	250	250	250
25	220	.....	14	314	280	280	280	280	270	250	.....	.....
26	220	220	314	306	338	280	280	.....	270	250	250	250
27	220	220	314	300	523	280	280	280	270	250	250	250
28	.....	220	314	300	499	280	280	280	270	.....	250	250
29	220	.....	300	.....	370	280	.....	280	270	250	.....	250
30	220	.....	300	300	523	280	280	280	.....	250	250	.....
31	220	.....	300	.....	862	.....	280	280	.....	250	.....	250
Mean	220	220	364	303	333	350	280	280	272	251	250	250

1895.

1	250	250	.....	250	385	280	280	280	.....	220	(a)	.....
2	250	250	.....	250	318	.....	280	280	270	220	(a)	220
3	250	.....	.....	250	300	280	280	280	270	220	.....	220
4	250	220	220	250	290	280	.....	.....	270	(a)	(a)	220
5	250	220	220	250	.....	280	280	280	270	(a)	(a)	220
6	.....	220	220	250	280	280	280	280	270	.....	(a)	220
7	250	220	220	14	280	280	.....	280	270	220	(a)	220
8	250	220	.....	343	280	280	280	280	.....	(a)	(a)	.....
9	250	220	220	733	280	.....	280	280	270	(a)	(a)	220
10	250	.....	.....	2,619	280	280	280	280	250	(a)	.....	220
11	250	220	220	1,301	280	280	280	.....	250	(a)	(a)	220
12	250	220	220	1,384	.....	280	280	270	250	(a)	(a)	220
13	.....	220	220	300	280	280	280	270	250	.....	(a)	220
14	250	220	220	74	280	280	.....	270	250	(a)	(a)	220
15	250	220	220	2,608	280	280	280	270	.....	(a)	(a)	.....
16	250	220	220	2,461	280	.....	280	270	250	(a)	(a)	220
17	250	.....	.....	1,698	280	280	280	270	250	(a)	.....	220
18	250	220	220	1,609	280	280	280	.....	250	(a)	220	220
19	250	220	220	1,400	.....	280	280	270	250	(a)	220	220
20	.....	220	220	1,271	280	280	280	270	(a)	.....	220	220
21	250	220	220	490	.....	280	.....	270	(a)	(a)	220	220
22	250	220	220	664	280	280	280	270	.....	(a)	220	.....
23	250	220	220	358	280	.....	280	270	220	(a)	220	220
24	250	.....	.....	385	280	280	280	270	220	(a)	.....	220
25	250	220	220	385	280	280	280	.....	220	(a)	220	.....
26	250	220	220	385	.....	280	280	270	220	(a)	220	250
27	.....	220	220	385	280	280	280	270	220	.....	220	250
28	250	.....	220	409	280	280	.....	270	220	(a)	.....	250
29	250	.....	220	409	280	280	280	270	.....	(a)	220	14
30	250	.....	220	409	280	.....	280	270	220	(a)	220	264
31	250	.....	.....	.....	280	.....	280	270	.....	(a)	.....	343
Mean	250	223	220	785	287	280	280	273	247	220	220	222

a Gates up; natural flow.

Daily discharge in second-feet of Cobbosseecontee River, at the upper dam, near Augusta, Maine—Continued.

1896.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	------	270	------	901	300	280	280	280	250	250	------	250
2	451	------	1,959	993	300	280	280	------	250	250	280	250
3	276	270	2,698	901	------	280	280	280	250	250	220	250
4	264	270	1,959	856	300	280	------	280	250	------	220	250
5	------	270	1,637	856	300	280	------	270	250	250	220	250
6	270	270	1,219	856	300	280	280	270	------	250	220	------
7	270	270	1,219	856	280	------	280	270	250	250	220	250
8	270	270	1,228	856	280	280	280	270	250	250	------	250
9	270	------	1,368	769	280	280	280	------	250	250	220	250
10	270	270	1,368	727	------	280	280	270	250	250	220	250
11	270	270	946	727	280	280	280	270	250	------	220	250
12	------	270	1,088	727	280	280	------	270	250	250	220	250
13	270	270	1,086	727	280	280	280	270	------	250	220	------
14	270	270	1,088	812	280	------	280	270	250	220	220	250
15	270	270	901	812	280	280	280	270	270	220	------	250
16	270	------	769	901	280	280	280	------	270	220	220	250
17	270	270	727	946	------	280	280	270	270	220	220	250
18	270	270	685	1,188	280	280	280	270	250	------	250	250
19	------	270	856	1,236	280	280	------	270	250	220	250	250
20	270	270	993	1,089	280	280	280	270	------	220	250	------
21	270	270	1,581	901	280	------	280	270	250	220	250	250
22	270	270	1,429	992	280	280	280	270	250	220	------	250
23	270	------	1,275	1,089	280	280	280	------	250	220	250	250
24	270	280	1,056	901	------	280	280	270	250	220	250	250
25	270	280	728	769	280	280	280	270	250	------	250	------
26	------	280	686	644	280	280	------	270	250	220	------	250
27	270	280	812	526	280	280	280	270	------	220	250	------
28	270	280	769	300	280	------	280	270	250	220	250	250
29	270	280	727	300	280	280	280	270	250	220	------	250
30	270	------	644	300	------	280	280	------	250	220	250	250
31	270	------	727	------	------	------	280	260	------	220	------	250
Mean	277	272	1,188	812	284	280	280	270	252	232	233	250

1897.

1	250	250	250	497	280	600	280	------	280	280	270	270
2	250	250	250	517	------	477	280	280	280	280	270	270
3	------	250	250	574	368	573	280	280	280	------	270	270
4	250	250	250	359	624	523	------	280	280	280	270	270
5	250	250	250	620	630	477	100	280	------	280	270	------
6	250	250	250	650	320	262	280	280	280	280	270	270
7	250	------	------	650	320	338	280	280	280	280	------	270
8	250	250	250	650	320	336	280	------	280	280	270	270
9	250	250	250	620	74	320	280	280	280	280	270	270
10	------	250	250	620	373	320	280	280	280	------	270	270
11	250	250	250	650	393	512	------	280	280	280	270	270
12	250	250	250	590	393	559	280	280	------	280	270	------
13	250	250	250	421	393	679	280	280	280	280	270	270
14	250	------	------	310	------	679	280	280	280	270	------	270
15	250	250	250	356	489	436	280	------	280	(a)	270	270
16	250	250	250	522	244	354	280	280	280	(a)	270	270
17	------	250	250	497	509	320	280	280	280	(a)	270	270
18	250	250	250	497	833	294	------	280	280	(a)	270	280
19	250	550	250	473	769	286	280	280	------	(a)	270	------
20	250	250	250	453	739	6	280	280	280	(a)	270	280
21	250	------	------	320	709	286	280	280	280	(a)	------	280
22	250	250	250	294	391	436	280	------	280	(a)	270	280
23	250	250	250	286	6	654	280	280	280	(a)	270	280
24	------	250	250	280	280	365	280	280	280	------	270	280
25	250	250	250	14	280	294	------	280	280	270	270	21
26	250	250	250	286	280	286	280	280	------	270	270	------
27	250	250	250	280	280	------	280	280	280	270	270	280
28	250	------	------	286	320	280	280	280	280	270	------	280
29	250	------	250	286	19	280	280	------	280	270	270	280
30	250	------	250	280	914	280	280	280	280	270	270	280
31	------	------	306	------	772	------	280	280	------	------	------	280
Mean	250	250	252	438	425	397	273	280	280	276	270	265

a Gates up; all that flows.

Daily discharge in second-feet of Cobbosseecontee River, at the upped dam, near Augusta, Maine—Continued.

1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	280	280	413	.....	478	280	280	280	270	250	250	250
2	.....	280	394	.....	478	280	280	280	270	.....	250	250
3	280	280	443	1,016	478	280	.....	280	270	250	250	250
4	280	280	408	1,068	455	280	19	280	.....	250	250	.....
5	280	280	408	1,068	455	.....	280	280	250	250	250	270
6	280	.....	387	1,068	433	280	280	280	250	250	.....	270
7	280	280	408	1,068	433	280	280	.....	250	250	250	270
8	280	280	589	1,068	278	280	280	280	250	250	250	270
9	.....	280	508	1,068	333	280	280	280	250	.....	250	270
10	280	280	474	1,008	333	280	.....	280	250	250	250	270
11	280	280	456	564	314	280	280	280	.....	250	250	.....
12	280	280	559	531	300	.....	280	280	250	250	250	270
13	280	.....	597	326	300	280	280	280	250	250	.....	270
14	280	280	681	326	300	280	280	.....	250	250	250	270
15	280	280	1,143	394	.....	280	280	280	250	250	250	270
16	.....	300	1,111	376	300	280	280	270	250	.....	250	270
17	280	300	1,089	413	300	280	.....	270	250	220	250	270
18	280	300	969	433	300	280	280	270	.....	220	250	.....
19	280	300	969	433	300	.....	280	270	250	220	250	270
20	280	300	1,016	433	300	280	280	270	250	220	.....	270
21	280	328	1,222	433	300	280	280	.....	250	220	250	270
22	280	328	1,184	433	.....	280	280	270	250	220	250	270
23	.....	328	1,147	433	300	280	280	270	250	.....	250	270
24	280	445	1,222	433	300	280	.....	270	250	220	.....	270
25	280	504	1,261	555	280	280	280	270	.....	220	250	.....
26	280	477	1,222	732	280	.....	280	270	250	220	250	270
27	280	435	1,125	682	280	280	280	270	250	220	.....	270
28	280	433	1,147	476	280	280	280	.....	250	250	250	270
29	280	.....	1,184	476	.....	280	280	270	250	250	250	270
30	.....	.....	1,147	620	280	280	280	270	250	.....	250	270
31	280	.....	1,147	.....	280	.....	.....	270	.....	250	.....	270
Mean	280	324	843	633	337	280	270	275	252	238	250	268

1899.

1	.....	270	270	300	300	280	280	280	270	(a)	160	160
2	270	270	270	306	300	280	.....	280	270	(a)	180	160
3	270	270	270	306	300	280	280	280	.....	(a)	180	.....
4	270	270	270	306	300	.....	19	280	270	(a)	170	180
5	270	.....	.....	359	300	280	280	280	250	(a)	.....	180
6	270	270	270	373	300	280	280	.....	250	(a)	180	180
7	270	270	250	395	.....	280	280	280	250	(a)	175	170
8	.....	270	270	502	300	280	280	280	250	(a)	170	150
9	270	270	270	842	300	280	.....	280	(a)	(a)	170	135
10	270	270	270	1,198	300	280	280	280	.....	(a)	150	.....
11	270	270	270	1,268	300	.....	280	280	250	(a)	150	120
12	270	.....	.....	984	300	280	280	280	250	(a)	.....	120
13	270	270	270	772	300	280	280	.....	250	(a)	150	120
14	270	270	270	809	.....	280	280	280	(a)	(a)	150	120
15	.....	270	270	809	280	280	280	280	(a)	(a)	140	120
16	270	270	270	787	280	280	.....	270	(a)	(a)	130	140
17	270	270	270	947	280	280	280	270	.....	(a)	130	.....
18	270	270	270	1,243	280	.....	280	270	250	(a)	130	140
19	270	.....	.....	1,387	280	280	280	270	(a)	(a)	.....	135
20	270	270	270	1,427	280	280	280	.....	(a)	(a)	160	135
21	270	270	270	1,408	.....	280	280	270	(a)	(a)	170	135
22	.....	270	270	1,331	280	280	280	270	(a)	(a)	180	135
23	270	270	270	1,145	20	280	.....	270	(a)	(a)	180	135
24	270	270	270	1,130	280	280	280	270	.....	(a)	180	.....
25	270	270	270	870	280	.....	280	270	220	(a)	180	.....
26	270	.....	.....	669	280	280	280	270	(a)	(a)	.....	150
27	270	270	270	635	280	280	280	.....	(a)	(a)	170	150
28	270	270	270	470	.....	280	280	270	(a)	(a)	165	140
29	.....	.....	280	324	280	280	280	270	(a)	(a)	150	140
30	270	.....	280	.....	280	280	.....	270	(a)	(a)	.....	140
31	270	.....	280	.....	280	.....	280	270	.....	.....	.....	.....
Mean	270	270	270	808	281	280	270	275	252	.....	162	144

a Gates up; all that flows.

MERRIMAC RIVER AT MANCHESTER, NEW HAMPSHIRE.

This stream receives the drainage from a considerable portion of the White Mountain area in New Hampshire. Its flow is regulated by a number of large lakes near the headwaters, the outlets of many of which are controlled by dams. The fall of the stream is considerable and developments of water power have taken place to an extent probably greater than in any other part of the United States. At Manchester records of the height are taken several times a day, generally on the even hours. Mr. H. W. Allen, of the Amoskeag Manufacturing Company, states that the ordinary flow of Merrimac River at that place for eight months of the year is 2,100 second-feet. With this quantity all the water wheels can be run. The minimum low-season flow for this year he would call 1,084 second-feet. The length of the main dam is 400 feet, and the wing 231 feet. The dam is 177.99 feet above mean tide water at the mouth of the river. Three-foot flashboards can be used in all months except March, April, and May, and then only 2-foot boards. The pondage extends to Hooksett, 8 miles, and covers 443.65 acres. The highest water on the dam of which there is record was on March 2, 1896, when there was 10.95 feet in height, flowing over. The drainage area above Manchester is 2,839 square miles.

MERRIMAC RIVER AT LAWRENCE, MASSACHUSETTS.

The longest and most careful series of computations of river flow are probably those kept at Lawrence, Massachusetts, having been begun by Mr. J. B. Francis for the Essex Company, and maintained by Mr. Hiram Mills and Mr. R. A. Hale. These extend over fifty years, but have never been published in full. The maximum, minimum, and mean discharge by months, from 1890 to 1897, has been printed in the Nineteenth Annual Report, Part IV, pages 113 to 115, and similar figures for 1898 have been given in the Twentieth Annual Report, Part IV, page 73, accompanied by a diagram showing the fluctuations from 1891 to 1898, inclusive.

Daily discharge of Merrimac River, at Lawrence, Massachusetts, in cubic feet per second.

1897.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2,807	3,776	3,963	14,238	9,957	9,153	5,642	9,220	3,074	2,647	2,374	5,150
2	1,943	2,931	3,636	14,616	10,049	8,090	7,037	8,574	3,467	1,872	2,782	4,406
3	2,180	2,775	3,669	15,348	10,908	7,394	6,497	7,539	3,840	440	4,666	4,246
4	4,009	2,740	4,780	15,908	11,538	7,673	5,470	6,576	2,438	3,449	9,216	3,591
5	4,000	2,730	5,943	16,067	12,514	9,028	5,010	6,352	2,547	2,757	7,604	3,216
6	4,816	1,902	6,944	18,116	11,949	10,517	5,454	6,877	2,864	2,544	5,474	6,430
7	6,707	2,390	8,042	21,048	10,727	10,469	4,805	6,374	4,460	2,570	3,897	8,992
8	7,325	5,779	10,500	22,974	9,443	9,068	4,725	5,027	2,854	2,496	4,879	7,925
9	5,285	7,946	9,385	22,611	7,829	8,397	4,969	5,164	2,685	1,534	3,741	6,598
10	4,032	9,427	9,125	24,513	7,613	15,264	3,803	4,551	2,760	340	4,109	5,971
11	5,005	9,094	10,100	24,483	6,582	40,872	3,393	4,575	2,072	2,542	5,680	5,172
12	3,990	7,589	12,300	21,510	7,714	35,923	4,841	5,043	1,424	2,498	6,950	5,334
13	3,313	6,214	13,680	17,953	8,840	26,829	3,370	5,006	3,736	2,582	8,033	8,124
14	3,364	4,821	13,350	16,235	14,051	21,473	16,921	4,280	2,934	2,669	7,923	9,850
15	2,989	5,429	11,243	15,873	24,681	19,643	32,498	3,729	2,644	2,428	7,441	15,100
16	2,026	4,759	10,365	18,789	19,305	17,539	41,499	4,983	2,684	2,454	6,259	32,300
17	1,834	4,539	8,904	23,407	14,171	14,996	26,568	4,073	2,658	1,892	6,231	36,800
18	4,030	4,343	8,472	23,271	11,448	12,675	16,203	4,159	1,930	3,805	6,909	28,504
19	3,231	4,392	8,092	20,629	9,481	11,416	13,672	4,721	1,044	2,770	7,378	20,203
20	3,104	3,398	9,216	18,710	8,301	9,217	11,173	4,522	3,717	2,716	6,019	14,157
21	2,965	3,467	11,156	17,085	7,607	10,348	9,853	2,860	3,020	2,502	4,801	12,113
22	3,025	4,847	13,373	14,605	6,657	10,297	9,137	3,169	2,804	2,390	5,331	10,563
23	2,357	4,306	13,627	13,078	5,752	9,375	8,650	5,118	2,768	1,525	4,960	10,878
24	2,322	3,812	16,735	12,203	6,313	7,931	9,098	3,520	2,446	398	4,851	9,169
25	4,049	4,241	18,717	13,761	5,676	7,117	10,241	4,480	1,886	3,096	3,022	9,170
26	2,997	4,036	17,871	15,884	6,716	6,877	12,121	5,467	1,370	2,566	5,424	7,065
27	2,783	3,427	15,549	16,933	8,226	6,478	11,661	5,285	4,019	2,341	4,390	7,633
28	2,771	2,869	12,944	15,214	9,060	6,376	10,466	3,996	3,087	2,506	7,816	6,116
29	2,699	.....	11,758	12,341	10,277	5,569	9,070	3,640	2,874	2,268	9,714	5,831
30	1,994	.....	11,498	10,947	10,626	5,246	9,782	5,007	2,671	1,648	6,924	5,653
31	1,721	.....	12,777	.....	9,616	.....	10,448	3,340	.....	176	.....	5,410
Mean	3,409	4,571	10,571	17,611	10,117	12,708	10,799	5,072	2,759	2,207	5,827	10,376

1898.

1	4,751	5,000	10,050	19,795	16,279	9,964	3,853	3,575	3,357	2,455	8,384	9,778
2	4,246	5,550	9,500	17,566	14,774	8,697	2,826	2,833	3,224	2,077	7,759	9,856
3	8,200	5,100	9,240	15,026	13,387	7,771	2,623	2,617	2,580	3,951	7,157	9,141
4	6,520	5,325	8,840	13,254	12,708	7,131	2,741	2,575	2,163	3,034	6,525	8,271
5	5,790	5,250	8,350	12,195	12,535	7,124	4,516	2,624	2,714	3,055	5,871	11,050
6	5,650	5,400	6,850	11,459	12,647	7,865	3,225	1,893	3,847	3,761	5,204	16,808
7	5,380	6,150	8,800	11,004	12,630	7,163	2,721	1,969	3,146	5,827	6,114	17,398
8	5,500	6,070	8,350	10,740	11,583	6,774	2,768	4,112	3,134	5,759	5,477	15,190
9	5,260	5,600	8,940	10,128	11,144	6,585	2,015	3,056	3,043	5,393	5,319	12,245
10	7,580	6,200	10,080	9,529	10,035	6,276	1,135	2,949	2,307	6,080	5,617	9,637
11	6,520	6,150	11,380	9,742	8,452	5,619	3,805	3,563	1,705	4,897	9,353	8,591
12	5,910	7,330	14,080	10,058	8,109	5,267	2,918	4,020	3,750	4,667	15,304	8,855
13	6,040	7,320	17,600	10,386	8,552	5,706	2,707	3,221	2,910	4,484	14,746	6,699
14	7,180	10,460	28,800	11,072	12,530	5,598	2,620	3,032	2,630	4,043	12,781	6,330
15	8,170	10,120	38,000	11,507	11,834	6,832	2,533	4,744	2,556	3,367	10,971	6,532
16	7,540	9,980	35,100	13,588	10,458	8,511	1,859	3,645	2,483	4,361	9,784	6,715
17	9,700	8,400	30,000	17,111	9,959	7,213	1,018	3,412	1,720	6,023	8,962	6,279
18	7,770	7,750	26,100	17,021	9,505	5,205	3,551	3,115	372	5,325	8,622	5,908
19	6,790	8,460	25,200	15,048	8,858	4,506	2,517	3,337	2,800	4,982	9,810	6,841
20	6,040	6,850	25,000	14,330	8,307	5,923	2,568	3,359	2,460	5,055	15,303	6,378
21	7,300	9,080	27,600	13,717	7,472	7,026	2,581	5,459	2,335	6,075	19,785	6,144
22	9,340	9,270	30,200	13,493	7,302	7,908	2,920	6,261	2,264	7,421	17,553	6,084
23	9,140	9,930	25,800	12,121	7,404	6,694	2,360	5,469	2,399	10,178	14,351	6,876
24	11,480	10,430	22,300	13,666	6,160	6,590	2,327	4,439	1,760	11,583	11,625	9,007
25	11,100	10,790	21,800	25,342	7,316	5,790	3,919	4,892	1,867	9,962	11,699	10,290
26	10,500	10,740	20,000	30,362	10,501	5,142	2,851	5,403	6,075	8,307	11,113	9,534
27	9,450	8,900	17,000	27,394	14,041	5,458	2,724	4,913	5,144	8,909	9,627	8,892
28	8,960	10,700	17,900	22,139	15,785	5,110	2,709	4,527	4,525	13,699	6,872	8,425
29	8,040	.....	18,000	19,424	15,081	4,567	2,713	5,306	4,198	14,473	6,253	6,572
30	6,620	.....	18,400	18,612	13,713	3,908	1,753	3,806	3,830	10,534	8,677	6,024
31	6,750	.....	19,700	.....	11,811	.....	1,081	3,657	.....	9,565	.....	5,792
Mean	7,394	7,797	18,612	15,229	10,996	6,464	2,660	3,799	2,910	6,429	9,887	8,779

Daily discharge of Merrimac River, at Lawrence, Massachusetts, in cubic feet per second—Continued.

1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	5,661	5,145	7,360	16,700	22,870	4,277	2,019	2,925	2,188	497	2,829	2,677
2	6,511	4,919	7,810	14,840	23,647	3,907	397	2,370	1,668	3,156	3,542	1,941
3	6,004	4,841	7,379	15,160	23,410	3,231	2,131	2,423	509	2,519	3,632	904
4	6,643	3,659	6,937	14,590	23,158	2,701	1,500	2,659	1,967	2,337	3,602	3,219
5	7,863	3,531	6,902	14,680	18,876	4,292	3,691	1,806	3,359	2,193	2,839	2,534
6	10,816	5,458	10,630	15,190	15,125	3,601	2,770	749	3,120	2,282	4,645	2,846
7	11,519	4,240	13,089	16,400	12,428	3,065	2,927	3,604	2,743	1,789	3,617	2,766
8	10,373	4,501	12,859	18,400	11,694	2,944	2,044	2,784	2,378	288	3,205	2,847
9	10,024	4,087	11,966	25,000	10,618	3,214	570	2,186	1,745	2,244	3,084	1,866
10	8,747	4,308	10,628	29,200	9,652	2,450	3,984	2,243	426	2,156	3,024	695
11	7,572	3,344	9,194	29,400	8,827	1,961	3,946	2,635	2,664	2,204	2,478	3,122
12	6,851	3,075	9,161	28,200	8,564	3,306	2,996	1,886	2,307	2,107	883	2,715
13	6,358	4,731	13,795	26,000	7,706	3,076	3,176	372	2,247	2,007	3,729	2,226
14	5,611	3,576	18,900	25,600	7,131	2,731	2,948	3,123	2,250	959	3,089	3,389
15	6,126	3,740	18,600	30,000	7,440	2,457	2,055	2,768	2,217	61	2,879	5,051
16	8,214	3,845	17,500	34,400	6,376	2,857	685	2,196	1,441	2,020	2,770	3,772
17	9,681	3,983	15,200	36,200	6,422	2,317	3,678	2,125	69	1,983	2,846	2,478
18	11,329	3,617	15,000	35,527	5,932	2,481	2,810	2,468	1,960	2,061	1,999	3,999
19	10,799	4,022	12,330	33,498	5,650	4,490	2,851	1,857	1,762	2,354	548	2,814
20	9,211	5,747	12,920	34,623	5,213	2,866	2,476	355	1,804	2,460	3,462	2,892
21	7,823	6,749	12,040	34,310	5,468	2,894	2,488	2,098	2,168	1,373	3,076	3,387
22	6,839	6,088	12,210	30,583	6,800	3,101	1,706	2,257	2,496	50	2,914	3,868
23	7,317	6,550	11,500	27,846	5,897	2,865	525	2,187	1,816	2,126	2,805	2,851
24	6,713	7,098	11,340	29,483	5,654	2,066	3,808	2,123	293	1,667	2,608	2,393
25	7,396	6,885	11,280	31,656	4,909	1,134	2,905	2,126	2,560	1,320	2,312	2,798
26	8,291	6,309	9,400	31,367	4,823	3,582	2,903	1,674	2,633	1,978	1,291	4,534
27	8,192	6,968	11,130	31,157	4,022	2,883	2,599	78	2,453	2,333	3,380	3,667
28	6,870	6,637	10,360	31,816	3,543	2,841	2,949	2,067	2,191	1,389	2,909	2,954
29	5,906	-------	11,240	26,805	5,255	2,506	2,241	2,153	2,453	123	2,789	2,916
30	6,808	-------	14,600	23,507	3,962	2,846	1,984	2,222	1,906	2,513	947	1,898
31	5,504	-------	17,200	-------	4,383	-------	3,781	2,132	-------	2,460	-------	593
Mean	7,857	4,882	11,948	26,438	9,528	2,980	2,481	2,086	1,994	1,789	2,792	2,797

NASHUA RIVER AT CLINTON, MASSACHUSETTS.

This river receives the drainage of a portion of central Massachusetts, and flows in a general northerly course into New Hampshire, emptying into Merrimac River. The principal part of the drainage basin is shown on the Worcester, Marlboro, Framingham, and Groton topographic atlas sheets. On its headwaters, near the town of Clinton, the metropolitan water board has under construction what is known as Wachusett reservoir, for the supply of Boston and neighboring towns. Measurements of the flow of Nashua River have been made at Clinton since July, 1896, but these have not been published, as there are unsettled claims for the diversion of the water. The rainfall on the watershed during 1897 was measured at four localities, and ranged from about 50 to 53 inches. The area and capacity of Wachusett reservoir are given for each 5 feet in elevation in the Report of the State Board of Health of Massachusetts for 1895 on "Metropolitan water supply," pages 127 and 128. The outline of the reservoir is also shown on an accompanying plan.

SUDBURY RIVER.

This small stream of eastern Massachusetts, receives water from an area west of Framingham. It flows in a northerly course through meadows and swamps, and joins Assabet River to form Concord River, which in turn continues northerly, entering Merrimac River immediately below the city of Lowell. Storage reservoirs have been constructed by the city of Boston, controlling the greater part of the flow from this basin. The available water has been systematically measured by Mr. Desmond FitzGerald, the record beginning in 1875. The run-off in cubic feet per second, by months, from 1875 to 1898, is given in the Twentieth Annual Report, Part IV, page 75.[1] The following is a continuation of this table. It should be noted that during August the yield of Sudbury River is a minus quantity.

Run-off of Sudbury River and Lake Cochituate watersheds in second-feet per square mile.

Month.	Sudbury River.		Lake Cochituate.	
	1899.	Averages, 1875–1899.	1899.	Averages, 1863–1899.
January	3.54	1.94	2.99	1.78
February	2.14	2.90	2.22	2.53
March	6.51	4.49	5.51	3.38
April	3.90	3.13	2.55	2.60
May	.79	1.68	.60	1.51
June	.10	.74	.10	.70
July	.08	.31	.03	.47
August	−.05	.48	.08	.67
September	.15	.38	.45	.65
October	.18	.83	.54	.92
November	.47	1.47	.45	1.33
December	.84	1.61	.35	1.46
The year	1.51	1.66	1.39	1.49

LAKE COCHITUATE.

This lake drains into Sudbury River below the point of diversion for the water supply of the city of Boston, and has been considered as a separate watershed, with an area of 18.87 square miles, of which 7.6 per cent is water surface. Dudley Pond, which lies just north of the lake, is connected with it, and water is occasionally drawn into the lake. The watershed of this pond is not included in the 18.87 square miles; thus a corresponding deduction must be made in computing the yield. This correction has been made in the accompanying table. Figures of catchment on this area since 1863 are available, these not being considered quite as accurate as those for Sudbury River. The results in inches of depth of run-off from the watershed are given in the following table. The average yield per square mile of this watershed for thirty-seven years, 1863 to 1899,

[1] For low water flow, see Engineering Record, September 16, 1899.

inclusive, is given in the second table, which shows by months the second-feet per square mile, the corresponding depth of run-off in inches, the depth of rainfall, and the percentage collected:

Yield of Lake Cochituate watershed in inches in depth.

[Drainage area, 18.87 square miles.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1863	1.91	3.12	3.71	4.41	1.44	0.66	2.94	1.54	0.99	1.31	2.64	2.19	26.57
1864	2.41	1.56	4.09	2.65	1.61	.49	.41	.67	.49	1.42	1.24	1.17	18.22
1865	2.06	1.76	4.66	2.71	4.75	.33	.46	.48	.44	.69	1.02	1.13	20.49
1866	.74	2.84	1.78	1.62	1.29	1.09	1.26	.64	1.32	.94	.97	1.55	16.08
1867	1.10	5.24	3.47	2.86	2.18	.66	.56	2.10	.31	1.05	1.11	1.12	21.77
1868	1.23	1.12	3.85	3.49	6.18	1.60	.46	1.15	1.82	.95	1.99	1.17	24.99
1869	1.82	1.87	3.33	2.48	2.17	1.05	.75	.59	1.11	2.33	1.30	3.16	21.96
1870	4.73	3.95	3.37	6.86	1.66	.97	.53	.40	.64	.96	.80	.78	25.06
1871	1.03	2.28	2.53	1.58	2.00	.87	.43	.70	.28	.61	1.23	1.18	14.74
1872	1.10	.89	1.35	2.96	1.10	1.48	.14	1.32	1.70	1.70	1.99	1.20	16.94
1873	3.10	1.58	3.90	6.08	2.66	.45	.61	1.43	.79	2.02	1.86	2.69	27.17
1874	3.12	2.20	1.84	3.18	2.79	1.96	.95	.92	.53	.52	.57	.51	19.09
1875	.15	2.98	2.66	3.17	1.39	1.50	.25	.61	.58	1.21	1.98	1.22	17.65
1876	1.08	1.77	5.20	4.21	1.43	.51	.85	.28	.58	.96	1.85	1.00	19.12
1877	1.20	1.37	6.81	3.24	2.04	.92	.64	.66	.40	1.12	2.69	1.97	23.06
1878	3.25	3.97	5.40	2.86	1.66	.76	.47	.84	.29	.73	2.07	4.04	26.34
1879	1.29	2.32	3.30	4.48	1.40	.77	.33	.95	.61	.60	.72	1.04	17.81
1880	1.47	2.24	1.79	1.57	.44	.06	.33	.23	.24	.28	.66	.59	9.90
1881	1.19	2.23	5.66	1.79	1.26	1.31	.16	.09	.23	.18	.84	1.40	16.34
1882	1.84	3.00	3.67	.93	1.55	.62	.06	.07	.97	.84	.58	.92	15.05
1883	.84	1.59	2.04	1.66	1.26	.07	.02	.07	.44	.44	.40	.94	9.76
1884	1.84	2.86	4.67	4.00	1.39	.67	.26	.61	.18	.34	.62	1.82	19.21
1885	1.90	2.00	2.21	2.36	1.61	.43	.00	.33	.25	.79	2.05	1.64	15.57
1886	2.28	7.93	3.51	2.52	1.09	.18	.25	.14	.30	.42	1.20	2.10	21.92
1887	4.06	4.34	4.70	3.36	1.35	.82	.72	1.33	.64	.49	.70	.96	23.47
1888	1.13	2.77	4.76	3.45	2.37	.53	.47	.94	2.31	2.57	4.21	5.46	30.97
1889	4.50	1.85	2.06	2.17	1.20	1.18	1.63	3.43	1.79	1.91	2.95	3.26	27.95
1890	1.92	2.04	5.87	2.23	1.85	1.41	.33	.46	1.40	3.40	1.49	2.11	24.51
1891	6.26	6.62	8.06	4.31	.88	.77	.50	.72	.76	.79	.83	1.26	31.73
1892	8.03	1.54	3.02	.90	2.03	.49	.33	.56	.60	.57	1.09	.84	15.62
1893	.64	2.55	4.12	2.42	1.83	.75	.38	.77	.42	1.06	0.83	1.46	17.27
1894	1.21	1.67	2.55	2.15	.91	.45	.38	.41	.46	.66	.92	1.14	12.91
1895	1.58	.75	3.50	3.35	.97	.40	.55	.50	.69	1.97	3.51	2.40	20.17
1896	1.72	3.69	5.53	2.01	.62	.71	.38	.47	1.03	1.28	1.40	1.31	20.14
1897	1.64	1.65	3.22	1.85	1.39	1.19	.75	.63	.46	.43	1.68	2.16	17.05
1898	2.27	4.06	3.11	2.69	1.86	.78	.37	1.30	.31	1.61	2.31	2.74	23.41
1899	3.45	2.31	6.35	2.84	.69	.11	.08	.09	.50	.63	.50	.41	17.91
Mean	2.056	2.662	3.828	2.908	1.738	.784	.539	.767	.725	1.059	1.482	1.677	20.220

Average yield per square mile of Lake Cochituate watershed, 1863 to 1899, inclusive

[Drainage area, 18.87 square miles.]

Month.	Second-feet per square mile.	Run-off in inches.	Rainfall in inches.	Per cent.
January	1.78	2.06	4.00	51.4
February	2.53	2.66	3.93	67.8
March	3.32	3.83	4.34	88.2
April	2.60	2.90	3.51	82.7
May	1.51	1.74	3.78	46.0
June	.70	.78	2.96	26.5
July	.47	.54	4.21	13.0
August	.67	.77	4.49	17.1
September	.65	.72	3.44	21.1
October	.92	1.06	4.56	23.2
November	1.33	1.48	4.38	33.9
December	1.46	1.68	3.40	49.3
The year	1.49	20.28	47.00	43.0

MYSTIC LAKE.

The area tributary to Mystic Lake lies about 10 miles north of Boston and contains 26.9 square miles, including about 3 per cent of water surface. It has been the source of water supply for the city of Charlestown since 1864. Upon the annexation of that city to Boston the source of supply passed into the control of the Boston waterworks, this being in 1876. The records of run-off extend from 1878 to 1897, inclusive. On January 1, 1898, the lake was abandoned as a source of water supply and records after that date are not available. The table given below is from the third annual report of the water commissioners of the city of Boston. These records are somewhat less accurate than those for Lake Cochituate, as they involve not only storage in Mystic Lake, which has been determined with a fair degree of accuracy, but also the quantity of water pumped by five engines, the slip of which was somewhat uncertain, and the flow through a fishway. There are also a number of other points on the watershed whose storage should have been considered.

The yield from this watershed in depth in inches for the years 1878 to 1897, inclusive, is given in the table on page 40. The average yield per square mile is given in the following table, these figures being obtained from the engineering department of the Metropolitan Water Board, through Mr. Charles W. Sherman, assistant engineer:

Average yield per square mile of Mystic Lake watershed, 1878 to 1897, inclusive.

[Drainage area, 26.9 square miles.]

Month.	Second-feet per square mile.	Run-off in inches.	Rainfall in inches.	Per cent.
January	1.81	2.09	4.21	49.5
February	2.72	2.86	4.04	70.8
March	3.39	3.91	3.72	105 2
April	2.33	2.61	3.02	86.1
May	1.62	1.87	3.64	51.5
June	.96	1.07	3.20	33.5
July	.49	.56	3.58	15.6
August	.56	.65	4.00	16.3
September	.47	.52	3.17	16.4
October	.69	.80	3.98	20.1
November	1.14	1.28	3.79	33.7
December	1.41	1.63	3.47	46.9
The year	1.46	19.85	43.82	45.3

Records are not available after 1897, although observations have been continued. The watershed is no longer in use as a source of supply, and so many complications enter into an estimate of yield that it is probable that it will not be computed.

Run-off in inches on Mystic Lake watershed, 1878 to 1897, inclusive.

[Drainage area, 26.9 square miles.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1878	3.55	3.97	4.91	2.21	2.16	0.78	0.48	1.11	0.56	0.71	1.75	3.68	25.82
1879	1.21	2.33	3.31	3.97	1.95	.97	.54	.70	.48	.34	.45	.69	16.94
1880	1.70	2.54	1.95	1.50	.96	.51	.67	.54	.45	.36	.44	.59	12.21
1881	.82	2.14	6.79	2.17	1.51	2.05	.87	.35	.31	.29	.50	.87	18.67
1882	1.37	3.08	4.19	1.16	1.85	.81	.95	.22	.58	.56	.39	.57	15.05
1883	.70	1.43	1.88	1.68	1.20	.52	.30	.22	.18	.39	.42	.44	9.31
1884	1.49	3.89	5.42	3.85	1.48	.85	.58	.60	.23	.27	.35	1.17	20.18
1885	1.79	1.81	2.05	2.08	2.18	.86	.47	.54	.34	.68	2.41	2.39	17.55
1886	2.31	7.70	3.91	3.24	1.27	.55	.41	.25	.32	.38	.88	1.43	22.65
1887	3.16	3.61	3.60	3.75	1.89	1.27	.87	1.35	.48	.57	.71	.91	22.17
1888	1.43	3.32	4.28	3.27	2.88	.84	.39	.54	1.31	2.74	5.04	5.08	31.12
1889	4.51	1.88	1.60	2.27	2.18	1.89	1.33	2.05	1.06	1.21	2.49	3.06	25.48
1890	2.07	2.23	5.37	2.93	3.00	1.92	.43	.46	.58	2.61	1.95	2.49	26.04
1891	6.29	5.97	7.21	3.43	1.40	1.01	.42	.44	.42	.58	.56	.87	28.60
1892	2.49	1.76	3.08	1.33	2.10	1.17	.66	.49	.56	.45	1.07	.87	15.96
1893	.75	2.14	4.52	2.73	4.42	1.04	.47	.69	.41	.55	.71	1.27	19.69
1894	1.37	1.87	3.05	2.27	1.31	.91	.49	.38	.36	.58	.91	.90	14.40
1895	1.55	.87	3.16	2.95	1.13	.54	.60	.30	.36	1.46	2.37	2.13	17.91
1896	1.85	3.40	4.50	3.26	.77	.75	.39	.34	1.06	.89	1.11	1.23	19.55
1897	1.39	1.40	3.46	2.14	1.83	2.19	.50	.95	.41	.39	1.02	1.96	17.64
Mean	2.09	2.86	3.91	2.61	1.87	1.07	.56	.65	.52	.80	1.28	1.63	19.85

CONNECTICUT RIVER AT HOLYOKE, MASSACHUSETTS.

This river, rising in northern New Hampshire and Vermont, flows in a general southerly course, forming the greater part of the boundary between these States, and crosses Massachusetts and Connecticut, emptying into Long Island Sound. Computations of discharge have been made in the southern part of its course at Holyoke, Massachusetts, a short distance above the Connecticut State line. The flow of the river is controlled at this point by the Holyoke Water Power Company. Data of stream flow have been obtained from Mr. A. F. Sickman, assistant engineer of the company. The quantities given are the daily amounts drawn from the pond above the dam, representing the discharge of the river excepting at such times as the surface falls below the crest, when water is ponded over night and Sunday. The results by months, from 1880 to 1895, are published in Bulletin No. 140, pages 37 to 41; for 1896 and 1897, in the Nineteenth Annual Report, Part IV, page 116; and for 1898, in the Twentieth Annual Report, Part IV, page 76.

Daily mean discharge in second-feet of Connecticut River at Holyoke, Massachusetts.

[Drainage area, 8,660 square miles.]

1896.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	47,350	5,500	66,950	34,400	18,300	6,550	3,900	2,300	2,700	4,650	12,050	17,900
2	39,050	4,850	112,050	36,100	16,050	6,350	3,800	2,450	2,850	4,700	11,750	15,750
3	29,700	5,350	103,450	32,300	14,700	6,450	2,350	3,900	2,700	3,600	11,550	12,300
4	23,850	4,850	65,050	24,650	15,000	6,200	750	3,700	2,700	3,500	12,100	8,250
5	12,200	4,800	37,900	19,600	14,350	5,800	1,700	3,750	2,100	4,550	12,800	6,450
6	9,300	5,550	25,100	18,550	13,900	4,650	2,050	3,650	700	4,600	26,800	6,500
7	7,750	17,150	22,050	18,350	13,700	3,850	2,900	3,800	6,150	5,200	30,450	8,550
8	7,300	20,750	19,050	17,550	13,550	5,100	3,450	2,850	7,750	5,250	25,300	8,850
9	7,600	19,700	17,950	17,700	11,900	4,900	4,450	4,100	8,050	5,550	23,900	9,700
10	7,850	17,700	16,900	19,900	11,000	7,100	6,050	4,650	7,200	4,750	21,000	13,900
11	7,100	14,300	14,050	22,700	11,050	8,850	4,500	4,000	6,450	4,300	17,650	13,800
12	7,250	11,650	10,900	26,950	10,700	8,750	4,300	3,750	4,800	4,500	15,800	11,000
13	8,250	10,600	9,350	37,300	10,700	7,750	4,150	3,750	3,900	4,250	15,050	10,400
14	8,250	9,600	9,300	59,350	11,000	6,450	4,100	3,800	4,400	6,600	12,550	9,900
15	7,700	8,750	8,900	71,100	11,000	6,600	4,000	2,050	4,100	10,200	11,600	9,350
16	7,900	7,600	8,550	77,500	9,050	5,950	4,150	1,300	3,800	20,100	11,400	5,950
17	7,700	7,800	8,950	84,450	7,800	5,700	4,100	2,800	3,650	16,850	10,700	4,300
18	5,800	6,400	10,350	89,200	7,650	5,050	2,650	2,800	3,450	14,750	10,000	4,650
19	6,450	6,250	10,750	88,600	7,700	5,050	450	2,800	2,350	13,950	9,650	5,000
20	7,400	6,600	25,250	81,200	7,350	4,250	4,200	2,800	4,650	13,300	9,150	5,150
21	7,100	6,400	29,250	71,050	7,150	3,500	3,900	2,800	6,200	14,150	7,900	6,050
22	7,100	5,550	25,150	61,950	6,900	4,300	3,400	2,800	6,850	18,300	8,150	5,250
23	6,950	5,150	22,300	54,600	5,900	4,400	3,700	550	8,450	22,100	9,450	4,750
24	6,900	6,550	18,400	46,450	5,650	4,450	4,300	3,300	8,100	21,850	8,750	3,900
25	6,200	6,800	15,300	38,300	6,050	4,300	4,150	3,350	6,850	20,500	8,400	3,650
26	6,000	6,500	15,050	30,800	5,800	4,350	4,100	3,300	4,550	19,500	10,500	4,200
27	6,800	6,300	19,750	26,750	5,850	2,550	4,550	2,950	4,250	16,800	13,300	3,400
28	6,350	6,100	23,250	23,150	4,850	3,300	4,450	2,700	4,500	14,500	13,600	4,550
29	6,100	9,600	22,250	20,900	5,350	4,050	4,300	1,900	4,450	13,000	14,600	4,400
30	6,100	.....	24,050	19,500	5,150	4,150	4,350	450	4,400	12,050	17,550	4,250
31	6,000	.....	26,150	.....	5,100	.....	4,000	2,800	.....	12,300	.....	4,300
Mean	10,882	9,096	27,216	42,363	9,684	5,357	3,684	2,965	4,768	10,971	14,115	7,624

1897.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3,350	3,900	4,400	21,900	32,950	22,900	10,200	22,350	6,200	4,950	3,850	21,050
2	3,350	3,600	3,550	22,950	27,800	19,300	9,550	18,950	6,150	3,450	4,550	16,650
3	3,350	3,600	3,500	25,150	28,000	16,750	9,900	16,050	5,300	3,350	17,050	12,800
4	4,700	3,750	4,450	24,600	27,100	16,100	9,550	13,950	4,550	5,000	19,400	10,700
5	4,700	4,300	5,700	27,050	27,500	18,100	8,100	12,800	4,600	4,350	15,850	11,150
6	7,550	2,950	7,550	37,100	26,350	19,600	7,650	12,750	4,800	3,400	13,200	16,800
7	10,100	2,550	11,750	46,250	23,900	20,350	7,950	10,550	4,650	3,150	10,100	15,600
8	10,350	11,100	12,150	44,900	20,550	19,050	9,950	8,750	4,500	3,250	9,850	18,700
9	8,400	13,600	10,550	42,150	17,050	20,200	13,200	8,950	4,450	2,950	9,150	16,850
10	8,600	14,250	10,250	45,150	16,150	60,600	11,950	8,400	4,450	1,300	14,900	16,500
11	7,500	11,150	12,550	36,250	14,500	75,350	9,350	9,150	3,650	3,550	18,050	15,850
12	6,650	8,400	15,700	31,350	15,400	56,950	8,550	13,650	2,550	3,000	17,850	16,650
13	5,900	6,500	15,300	26,600	17,500	41,300	13,050	12,600	5,050	3,900	16,200	22,950
14	5,100	7,250	13,050	25,550	35,800	35,300	37,000	10,200	3,900	5,100	13,700	23,600
15	4,750	6,150	12,250	28,700	44,050	30,000	57,250	8,150	3,450	5,300	12,900	59,850
16	3,750	5,100	10,300	41,300	36,550	24,500	58,350	9,600	3,450	4,400	11,550	70,650
17	3,450	5,200	9,150	48,550	30,000	21,050	50,200	9,150	4,000	2,050	15,400	63,850
18	5,100	5,250	8,200	50,950	24,900	17,800	39,350	11,050	3,700	4,900	19,300	52,600
19	4,900	4,950	8,100	49,350	19,700	15,250	31,350	12,300	2,250	4,700	17,700	37,050
20	4,900	3,950	15,650	44,500	16,850	12,300	23,250	11,800	3,700	4,350	14,600	25,550
21	4,400	3,600	23,750	39,700	14,600	13,300	18,750	9,750	3,550	3,900	12,700	18,950
22	4,700	4,950	23,750	34,500	13,600	13,800	17,550	9,050	3,550	4,650	12,650	15,750
23	3,350	4,900	25,850	30,250	12,450	12,750	19,350	8,650	3,950	2,900	12,350	14,100
24	3,000	4,800	34,650	27,300	13,400	11,250	21,400	8,750	4,650	3,050	11,150	13,200
25	4,100	4,850	33,350	29,050	14,050	10,000	20,550	9,400	4,450	4,400	8,250	10,350
26	3,500	4,850	25,850	34,650	16,250	8,300	21,100	9,700	4,050	3,750	9,000	8,950
27	3,350	3,700	18,600	37,350	18,950	7,900	27,300	9,500	5,150	3,700	22,050	10,450
28	3,600	2,700	16,750	37,250	20,350	9,950	24,800	7,850	4,950	3,150	29,550	10,450
29	4,200	.....	16,350	36,950	23,050	9,700	44,150	7,050	4,900	3,100	28,300	9,550
30	2,300	.....	16,250	37,050	24,600	9,900	53,650	7,250	4,850	3,050	25,250	9,050
31	2,400	.....	19,350	.....	24,350	.....	32,900	6,450	.....	1,750	.....	8,950
Mean	5,011	5,780	14,471	35,478	22,524	22,320	23,458	10,792	4,313	3,668	14,880	21,779

Daily mean discharge in second-feet of Connecticut River at Holyoke, Massachusetts—Continued.

1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	7,650	7,000	8,100	43,500	23,800	14,300	6,000	4,750	5,000	6,300	16,250	12,050
2	7,500	6,600	8,400	37,300	22,150	12,950	6,050	3,800	4,650	4,650	14,050	12,600
3	7,700	7,050	8,050	29,550	20,450	11,550	5,600	3,450	3,600	5,600	12,700	11,500
4	7,650	7,350	8,050	25,850	20,550	10,250	4,800	3,650	3,550	5,050	11,550	11,100
5	7,750	6,900	7,500	22,450	22,100	8,650	4,550	4,700	4,000	6,600	10,700	14,150
6	7,650	6,350	6,950	20,450	22,650	9,200	4,250	4,350	5,500	23,000	8,950	15,250
7	8,100	7,500	7,800	19,400	20,850	9,000	3,300	4,800	6,850	15,500	10,350	14,800
8	9,050	7,350	8,000	18,400	17,950	8,800	3,450	6,250	6,550	12,550	9,850	13,050
9	8,600	7,350	8,550	16,950	17,300	8,000	3,850	6,150	5,950	12,200	9,700	11,550
10	8,750	7,650	9,650	16,050	15,600	8,050	2,850	5,750	5,050	11,650	10,850	12,250
11	8,450	7,850	11,750	18,650	14,400	7,600	4,400	5,450	3,550	9,550	28,750	9,900
12	8,300	8,100	16,950	20,000	14,400	8,300	4,250	4,800	5,050	8,600	29,150	9,400
13	8,750	9,250	30,700	21,950	18,250	10,500	3,850	4,000	4,850	7,800	21,350	5,800
14	13,150	12,250	66,500	23,950	22,000	15,000	3,450	3,150	3,500	7,200	18,800	5,850
15	12,300	12,450	74,900	26,300	22,450	17,900	3,600	4,750	3,900	7,200	16,600	6,150
16	15,450	11,750	64,700	35,750	23,850	17,000	3,200	3,800	4,700	9,800	14,950	6,400
17	14,700	10,400	53,500	37,000	22,500	15,850	600	3,500	3,550	11,550	13,700	6,050
18	11,850	9,900	50,750	34,200	19,200	13,800	4,050	3,450	650	10,400	13,500	6,600
19	10,000	9,350	55,850	31,500	16,550	12,200	3,350	4,600	4,200	10,150	16,200	7,250
20	9,700	8,750	59,750	28,500	15,150	14,800	3,500	3,950	3,550	11,950	24,550	6,500
21	12,950	9,850	76,150	27,350	14,500	14,350	3,250	4,550	3,400	12,650	26,650	6,500
22	16,050	9,350	68,600	25,400	12,350	13,800	3,200	5,350	3,300	13,250	23,750	7,200
23	14,650	9,250	52,100	23,300	12,450	12,800	3,200	4,850	3,200	16,000	20,700	8,550
24	15,000	9,200	49,050	28,450	13,050	11,750	2,250	4,750	3,000	15,450	18,000	11,550
25	13,100	9,000	44,250	46,850	14,550	10,500	4,100	6,700	6,950	13,450	16,450	12,300
26	11,300	8,800	37,900	50,450	23,300	9,050	4,350	7,550	12,000	12,050	14,200	12,650
27	10,500	7,650	35,450	46,700	23,600	9,750	4,450	5,850	12,550	17,850	12,750	11,000
28	9,700	8,600	38,500	39,200	26,800	9,100	4,600	4,950	12,050	22,400	10,850	9,650
29	8,500	.....	41,550	33,500	22,350	8,500	4,500	6,950	10,050	21,000	8,850	8,450
30	8,050	.....	43,900	28,450	19,450	7,550	3,400	6,950	8,000	18,700	10,550	7,600
31	7,650	.....	46,100	.....	16,900	.....	1,500	6,150	.....	18,300	.....	7,700
Mean	10,339	8,673	35,482	29,245	19,079	11,395	3,798	4,958	5,423	12,207	15,840	9,689

The figures for 1899 have not been computed at this time, April, 1900.

CONNECTICUT RIVER AT HARTFORD, CONNECTICUT

Observations of the height of Connecticut River are maintained at a point near Hartford by the Connecticut River Bridge and Highway District, Edwin D. Graves, chief engineer, as noted in the Twentieth Annual Report, Part IV, page 77. Daily readings, beginning February 8, 1896, have been obtained, and are given below. Computations of discharge of the river at this point from 1871 to 1886 have been printed in the Fourteenth Annual Report, Part II, beginning on page 140. The gage now being read was placed at the same elevation as the old gage established by the Engineer Corps, United States Army, about 1872.

Daily noon gage height in feet of Connecticut River at Highway Bridge, Hartford, Connecticut.

1896.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	.....	18.0	10.6	7.7	3.5	2.5	1.7	1.5	3.0	3.7	7.0
2	.....	.....	20.0	11.3	7.6	3.7	2.0	1.5	1.5	2.8	3.6	6.8
3	.....	.....	26.5	12.0	7.0	3.7	2.1	1.6	1.9	2.7	3.7	6.0
4	.....	.....	25.6	11.6	6.5	3.5	2.2	2.4	2.4	2.5	4.0	5.5
5	.....	.....	20.0	10.0	6.4	3.5	2.3	2.0	2.7	2.4	4.8	4.4
6	.....	.....	16.0	9.5	6.0	3.3	2.3	1.8	3.3	3.0	6.0	3.2
7	.....	.....	13.0	9.0	5.8	3.0	2.3	2.5	3.6	4.1	10.0	4.0
8	.....	12.5	9.0	8.5	5.7	2.6	2.3	1.7	4.4	3.2	10.6	4.0
9	.....	12.5	7.8	7.6	5.7	3.0	2.4	2.0	4.0	3.3	10.0	5.0
10	.....	11.4	6.3	7.5	5.5	3.0	2.4	2.6	3.6	3.4	7.6	5.0
11	.....	10.3	5.3	7.8	5.2	3.5	2.4	2.7	4.3	3.4	7.4	6.5
12	.....	9.0	4.8	8.3	5.0	4.0	2.4	2.4	4.0	3.7	6.7	6.4
13	.....	7.3	4.4	10.0	4.6	4.4	2.4	2.4	3.6	3.8	6.4	5.3
14	.....	6.5	4.5	12.0	4.6	4.5	2.0	1.8	3.4	4.4	6.0	5.0
15	.....	6.3	4.5	15.0	4.7	4.4	2.4	1.9	2.8	5.0	5.5	4.8
16	.....	6.3	4.5	16.0	4.7	4.3	2.5	2.0	2.3	4.9	5.0	4.7
17	.....	6.3	4.6	18.0	4.2	4.0	2.7	1.8	2.4	4.7	4.5	2.5
18	.....	6.3	4.8	20.8	3.5	3.7	2.5	1.7	2.0	4.5	4.0	4.0
19	.....	6.3	4.9	22.0	3.4	3.7	1.5	1.6	2.3	4.4	4.0	4.5
20	.....	6.0	8.0	22.2	3.7	3.2	.6	1.5	2.7	4.0	3.8	4.6
21	.....	5.3	10.8	21.0	3.5	3.0	1.3	1.5	3.2	4.0	4.0	4.7
22	.....	5.3	11.4	19.8	3.4	2.4	2.0	1.5	3.5	4.0	4.0	4.5
23	.....	5.5	10.0	18.4	3.0	2.4	2.2	1.6	3.4	4.8	4.0	4.3
24	.....	5.9	9.0	17.0	2.8	2.5	2.0	1.6	3.4	5.2	4.5	4.2
25	.....	6.0	8.0	15.5	3.6	2.0	2.6	1.7	3.4	5.7	4.0	3.9
26	.....	6.0	7.0	13.5	3.3	2.4	2.7	1.5	3.3	6.0	4.6	3.7
27	.....	11.0	6.0	11.0	3.0	2.6	2.7	1.5	3.5	5.5	5.0	3.5
28	.....	14.0	6.9	11.0	3.4	2.8	2.8	1.5	3.6	5.0	5.5	4.0
29	.....	16.5	8.9	9.0	3.4	3.0	2.7	1.5	3.7	5.0	5.9	3.5
30	.....	.....	9.5	8.0	3.5	2.0	2.6	1.6	4.0	5.0	6.5	4.0
31	.....	.....	9.8	.....	3.5	.....	2.5	1.6	.....	4.0	.....	3.5

1897.

1	3.4	3.7	3.8	8.8	13.5	10.0	5.0	17.0	4.3	2.5	3.0	9.5
2	3.4	3.8	4.0	9.6	12.4	9.0	5.1	13.0	3.8	3.3	3.9	8.0
3	3.4	3.9	3.8	9.8	11.7	8.0	5.0	10.5	4.6	3.5	5.0	6.8
4	3.4	4.5	4.8	10.2	11.0	8.0	4.8	8.6	3.9	3.0	8.0	6.0
5	4.8	4.0	5.0	10.5	11.4	7.0	4.8	8.5	3.5	2.7	7.3	6.0
6	5.9	3.8	6.5	12.2	11.0	8.0	4.5	8.2	3.3	2.6	6.8	7.4
7	5.7	4.1	7.0	13.5	10.3	6.7	4.2	7.7	3.3	2.7	5.6	10.0
8	5.6	6.8	8.2	15.5	9.3	8.6	4.0	6.7	3.3	2.8	4.7	9.7
9	5.5	9.4	7.5	15.3	7.6	7.1	5.0	5.5	2.8	2.8	4.6	8.8
10	5.5	9.5	6.8	17.4	7.4	12.0	5.8	5.5	2.8	2.0	4.7	8.0
11	4.5	9.0	7.1	17.0	7.0	18.0	5.0	5.0	3.3	1.6	5.5	8.0
12	5.0	8.1	8.0	15.2	6.5	20.6	4.6	7.2	3.0	3.0	8.0	8.0
13	4.5	7.0	9.0	13.7	7.0	18.3	5.0	8.2	3.0	2.5	8.5	9.1
14	3.9	6.4	8.9	11.4	9.6	16.3	11.5	7.0	3.2	2.8	7.8	11.5
15	3.5	5.7	8.8	10.8	15.0	13.8	18.6	6.2	2.8	3.0	6.8	14.0
16	4.0	5.8	7.8	11.0	14.7	12.0	20.8	5.0	3.0	3.0	6.0	19.6
17	3.0	5.4	6.7	15.0	14.0	10.1	20.0	6.8	3.0	2.6	5.8	20.4
18	3.4	5.2	5.6	16.5	12.1	9.0	18.3	6.9	3.0	2.4	6.5	19.0
19	3.5	5.5	5.6	17.3	10.5	8.0	16.8	6.0	2.9	2.8	7.5	16.0
20	3.8	5.4	7.8	16.7	9.4	7.2	14.0	6.0	2.8	3.0	7.6	13.0
21	4.3	5.3	10.0	15.6	8.0	6.0	10.0	6.5	2.8	3.7	7.1	9.4
22	4.5	5.2	11.0	14.5	7.9	6.0	9.0	5.0	2.6	4.0	6.5	8.0
23	3.9	5.9	11.0	13.0	6.8	6.0	12.2	5.3	2.7	3.7	6.0	6.5
24	3.5	6.2	12.2	11.8	6.4	5.8	12.7	5.2	3.0	3.6	5.5	5.5
25	3.2	5.6	13.8	11.8	6.3	5.3	12.7	4.9	3.0	3.2	5.0	6.2
26	2.7	5.0	12.8	12.0	6.7	4.6	11.5	5.2	3.0	2.7	5.3	7.5
27	2.6	5.0	11.4	13.3	7.0	4.4	10.2	6.0	3.0	4.0	6.0	8.5
28	2.8	4.0	9.8	13.5	8.0	3.8	12.0	5.2	3.0	3.0	9.0	8.6
29	3.0	.....	8.5	13.4	8.6	4.4	12.4	5.6	2.9	3.0	11.0	8.6
30	3.6	.....	7.8	13.5	9.2	4.7	19.3	4.2	3.4	3.0	10.4	8.6
31	3.7	.....	8.0	.....	10.0	.....	20.6	4.5	.....	3.0	.....	8.4

Daily noon gage height in feet of Connecticut River at Highway Bridge, Hartford, Connecticut—Continued.

1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	8.0	7.8	6.0	15.4	13.2	8.0	4.5	4.0	3.7	5.0	8.1	.....
2	7.7	7.8	5.8	15.5	12.5	7.0	4.2	4.0	3.2	4.0	7.4	6.5
3	7.5	7.8	5.6	13.8	11.6	6.7	4.0	4.3	3.0	4.5	6.6	6.6
4	7.4	7.7	5.4	12.4	10.9	6.4	4.0	4.6	3.0	3.2	6.3	7.5
5	7.2	7.6	5.0	10.5	10.0	6.2	4.0	4.5	3.0	4.0	5.8	8.5
6	6.9	7.5	4.6	9.9	10.4	6.0	3.8	4.4	3.2	6.1	5.6	9.5
7	6.8	7.4	4.9	9.4	10.5	5.8	3.4	4.2	3.4	9.0	5.4	8.8
8	7.5	7.3	5.4	9.0	9.8	5.6	3.0	4.0	3.7	6.0	5.1	8.5
9	7.4	7.3	5.8	8.6	9.0	4.8	3.0	3.9	3.6	5.8	5.3	7.3
10	7.3	7.5	6.4	8.5	8.4	4.7	2.8	4.0	3.7	5.6	5.0	6.2
11	7.2	7.5	6.8	8.4	7.9	4.5	2.7	3.8	3.4	5.1	8.6	6.3
12	7.0	7.4	8.0	8.7	7.6	4.7	2.6	3.2	3.0	5.0	13.0	6.3
13	6.8	8.5	10.8	9.0	8.0	5.0	2.4	3.5	3.0	4.5	12.0	5.8
14	8.1	9.7	17.4	9.5	9.6	6.5	2.2	3.4	3.2	5.0	10.0	5.7
15	9.5	9.8	20.0	9.7	9.8	8.0	2.0	3.2	3.2	5.5	9.0	5.9
16	9.8	9.0	21.0	10.0	10.2	7.7	1.9	3.0	3.4	5.8	7.9	6.0
17	9.8	8.4	20.0	12.0	10.4	7.4	1.8	2.7	3.0	6.0	7.6	6.0
18	8.8	7.6	19.0	14.5	10.2	7.0	1.6	2.6	2.5	5.8	7.2	5.9
19	7.5	7.8	18.0	18.0	9.0	7.2	3.0	2.6	2.0	5.5	10.0	6.0
20	6.0	8.2	18.8	12.2	8.2	7.4	3.1	4.0	2.2	5.7	11.3	6.0
21	8.2	12.0	19.1	11.6	7.8	7.5	3.1	4.6	3.2	6.3	12.4	6.0
22	10.0	12.0	21.2	12.5	7.3	7.0	3.3	3.9	2.4	7.2	11.7	5.9
23	10.6	10.3	20.5	13.5	6.8	6.5	3.3	3.7	3.2	7.1	10.7	6.0
24	11.4	9.0	18.2	14.5	7.4	6.0	3.4	3.4	3.0	7.0	9.6	6.0
25	10.4	7.8	17.3	15.5	8.0	5.8	3.5	4.4	4.5	7.2	9.0	7.7
26	9.0	6.8	16.5	16.5	10.0	5.5	3.5	5.2	5.5	6.6	8.2	7.5
27	9.0	6.5	15.5	17.0	11.2	5.4	3.6	4.9	6.3	7.1	7.5	7.0
28	8.5	6.0	14.5	16.5	13.6	5.1	3.7	4.0	6.6	9.7	6.4	6.5
29	7.8	.....	14.8	14.9	12.7	4.8	3.8	4.0	6.3	9.7	6.1	6.5
30	7.5	.....	15.3	14.0	11.8	4.5	3.8	4.3	5.0	9.2	6.0	6.4
31	7.0	.....	15.4	.....	10.3	.....	3.9	4.5	.....	8.7	.....	6.7

1899.

1	7.5	6.0	8.7	9.2	19.3	4.0	2.7	3.1	2.2	1.5	4.5	3.5
2	7.6	5.7	8.7	9.3	18.4	4.0	2.7	2.5	3.0	.6	4.7	3.6
3	7.7	5.6	8.5	9.5	18.1	4.0	2.8	3.0	2.7	.8	4.8	3.7
4	7.7	5.4	7.5	9.2	18.0	3.7	2.9	2.9	2.9	1.9	4.9	3.8
5	7.8	5.5	7.2	8.5	17.0	3.4	2.9	3.4	3.0	2.2	5.0	3.9
6	10.2	5.7	8.7	8.6	15.8	3.3	3.0	3.6	2.8	2.1	5.0	4.0
7	11.5	5.6	9.8	9.0	14.0	3.2	3.0	2.5	2.7	2.1	5.0	4.2
8	11.0	6.2	9.0	11.0	12.5	3.7	3.0	2.5	2.7	2.0	4.5	4.3
9	10.5	5.6	8.6	13.1	10.9	3.0	3.1	2.6	2.8	2.0	4.4	4.4
10	8.0	5.0	8.0	15.4	9.4	3.0	3.1	2.2	2.5	2.5	4.3	4.5
11	8.5	4.5	7.5	15.1	8.5	3.0	3.2	2.2	2.2	2.5	4.2	4.6
12	8.6	4.5	8.5	14.5	8.0	3.0	3.2	2.2	2.3	2.5	4.1	4.7
13	8.2	4.5	9.7	15.1	7.5	2.7	2.5	2.2	2.3	2.4	4.0	4.8
14	8.0	4.7	11.0	15.5	7.0	2.6	2.6	2.8	2.8	2.5	4.5	4.8
15	8.1	5.0	11.0	18.5	6.5	2.6	2.6	2.2	2.4	2.7	4.0	4.8
16	8.2	5.2	11.2	20.0	6.5	2.6	2.7	2.6	2.2	2.8	3.5	4.8
17	8.5	5.5	10.5	21.5	6.2	3.0	2.7	2.4	2.8	2.9	3.5	4.8
18	10.0	5.5	9.5	20.6	6.0	3.0	2.7	2.5	2.8	3.0	3.5	4.8
19	9.5	5.5	9.7	20.2	5.7	3.0	2.8	2.2	2.4	2.5	3.4	4.7
20	8.5	6.0	10.1	20.5	5.5	3.0	2.9	2.4	2.7	2.0	3.4	4.6
21	7.9	6.5	9.2	21.5	5.5	3.0	2.9	2.2	2.6	2.2	3.4	5.0
22	7.3	6.6	8.4	21.2	5.5	3.0	3.0	2.0	2.2	2.4	3.6	4.9
23	6.8	6.8	7.8	20.9	5.5	3.4	3.0	2.6	2.5	2.6	3.7	4.8
24	7.0	7.2	7.7	20.8	5.2	3.3	3.1	2.2	2.1	2.8	3.9	4.7
25	8.0	7.1	7.4	21.3	5.2	3.2	3.0	2.0	2.7	3.0	4.0	4.6
26	8.0	7.7	7.0	21.6	4.6	3.1	4.2	2.7	3.0	3.0	4.5	4.6
27	8.0	7.7	6.5	22.0	4.5	3.0	3.7	2.6	3.0	3.0	5.0	4.5
28	7.5	8.5	6.5	21.9	4.3	2.9	4.4	2.5	2.8	4.0	5.0	4.4
29	7.0	.....	7.5	21.0	4.2	3.2	4.2	3.2	3.1	4.1	5.0	4.3
30	6.5	.....	8.8	20.0	4.5	2.7	3.0	3.2	3.0	4.2	3.4	4.3
31	6.2	.....	9.0	.....	4.3	.....	2.5	2.8	.....	4.3	.....	4.1

MOHAWK RIVER AT RIDGE MILLS, NEW YORK.

Mohawk River rises in Lewis County, New York, and flows southerly through Oneida County, and turning to the east finally empties into Hudson River. It is shown through the greater portion of its length on the Oneida, Oriskany, Utica, Fonda, Amsterdam, Schenectady, and Cohoes topographic sheets of the United States Geological Survey. The measurements on this stream and its tributaries were instituted as previously described on page 20 by Mr. George W. Rafter for the United States Board of Engineers on Deep Waterways. The station at Ridge Mills is located at the dam of the Rome waterworks, 3 miles above Rome. The drainage area of the Mohawk River at this point is 153 square miles. Two gages are read twice a day by Daniel Brown, engineer at pumping station—one above the dam showing the height on the crest and one in the tailrace in order to determine the head on the wheels. The crest of the dam has an irregular profile, and in order to facilitate computation is divided into three parts. The flow over section A was computed from Bazin's experiments of November and December, 1895, series No. 162, with $q=8.025\ mLH^{\frac{3}{2}}$. The flow over sections B and C, which is over flashboards, is computed from Francis's formula for sharp-crested weirs. Experiments were conducted at Cornell University on an experimental weir corresponding to Bazin's series No. 162, and from the coefficients obtained a discharge curve plotted to correspond with the discharge curve of Bazin's. All computations of flow at this point made before June 1, 1899, were made by using Bazin's coefficients, but in subsequent computations the Cornell coefficients were used. The dam is of timber, backed with stone, and has very little leakage.[1]

[1] On flow of water over dams, by George W. Rafter: Proc. Am. Soc. Civ. Eng., March, 1900, Vol. XXVI, No. 3, p. 311.

Estimated daily discharge in second-feet of Mohawk River at Ridge Mills, New York, for 1899.

[Drainage area 153 square miles.]

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	339	262	218	.....	93	75	339
2	319	252	233	.....	208	75	75
3	279	232	248	.....	233	105	75
4	259	249	131	.....	253	135	129
5	214	202	146	.....	200	95	158
6	232	127	131	.....	310	135	158
7	232	262	126	.....	290	145	172
8	262	323	121	.....	260	135	190
9	259	669	125	85	290	135	575
10	279	499	129	85	310	165	575
11	249	379	139	85	340	125	147
12	282	359	169	95	260	135	.....
13	282	339	265	89	310	145	.....
14	302	339	245	85	260	145	.....
15	402	319	275	99	310	145	.....
16	399	399	295	115	240	145	115
17	359	519	230	135	220	135	158
18	339	399	230	112	290	135	158
19	282	382	245	85	290	145	.....
20	279	339	245	79	290	165	.....
21	262	302	265	79	240	165	.....
22	259	382	295	56	260	145	151
23	299	299	272	56	260	145	151
24	259	282	289	56	310	145	129
25	259	275	262	60	540	135	151
26	259	262	289	69	220	145	172
27	249	289	309	69	310	135	172
28	249	165	309	53	340	165	172
29	249	133	278	53	360	.....	172
30	229	178	315	79	260	.....	339
31	.....	178	200	.....	260	.....	339
Mean	281	310	226	81	278	136	207

NINEMILE CREEK AT STITTVILLE, NEW YORK.

This stream rises in the northern part of Oneida County, New York, and flows south into Mohawk River. A portion of its course is shown on the Oneida topographic sheet of the Geological Survey. Observations were made on this creek at Stittville, which is reached by the Rome, Watertown and Ogdensburg Railroad. The drainage area of Ninemile Creek at Stittville is 63 square miles. The station was located at an old timber dam built to furnish power to a gristmill and sawmill. One gage was read at the bridge above the dam, giving the height on crest, and one at tailrace below the dam, which, with the upper gage, gave the head on wheels. The dam had a somewhat irregular crest, but was repaired by the Board on Deep Waterways. The flow over section *A*, which is the bulkhead, is computed from Bazin's experiments in October, 1887, series No. 115, with $q=8.025mLH^{\frac{3}{2}}$. The flow over section *B*, which is a spillway, is computed from Bazin's experiments of July, 1894, series 130, with $q=8.025mLH^{\frac{3}{2}}$. A new curve was later drawn, based upon experiments carried on at Cornell University, corresponding to Bazin's series, Nos. 115 and 120. This dam leaks badly, so that low-water flows are of questionable accuracy. There are in the mill two standard Leffel wheels, one a 23-inch wheel and the other a 40-inch wheel, and a record was kept of the head on

the wheels and the amount of openings, so that the quantity of water passing through the wheels can be computed. The results obtained from this station were of such questionable accuracy that the station was abandoned on June 30, 1899.

ORISKANY CREEK AT COLEMAN, NEW YORK.

This stream rises in Oneida County, New York, and flows in a northerly direction, emptying into Mohawk River. It is shown through a part of its course on the Oriskany topographic sheet of the United States Geological Survey. Observations for the computation of flow of Oriskany Creek have been made at Coleman, 5 miles above the junction of the creek with Mohawk River, and at Oriskany, 2 miles farther down. The station at Coleman was located at Reeders Mills. The dam located here impounds water to furnish power for the picking mill and cotton mill on the west bank and for the gristmill and sawmill on the east bank. The gages were read above the dam, giving the height on crest, and in the headraces and tailraces of each of the mills, giving the heads on wheels. The dam is of earth, with a timber crest, irregular in profile. For convenience in computation the crest has been divided into nine parts. The flow over this dam was computed from Bazin's experiments of November, 1895, series No. 170. The station was established September 20, 1898, and continued until February 28, 1899, when it was abandoned.

ORISKANY CREEK AT ORISKANY, NEW YORK.

The drainage area of Oriskany Creek at this station is 144 square miles. The flow is measured over the State dam, the gage showing the height on crest being located on the left bank just above the dam. The crest is of irregular profile, and in order to facilitate computation is divided into three parts. No experiments have been made to determine coefficients for a dam of this section, so it was considered by Mr. George W. Rafter that the mean between the coefficients obtained by Bazin in his experiments, series Nos. 141 and 117, would best fit the conditions at this dam. Experiments were afterwards conducted at Cornell University on a similar section. For a cross section of this dam reference should be made to the paper on "Flow of water over dams," by George W. Rafter: Proc. Am. Soc. Civ. Eng., March, 1900, p. 312. All computations of discharge up to June 1 were made from coefficients as determined by Bazin; all subsequent observations have been computed by using the Cornell coefficients. Water passing through the Erie Canal feeder is determined by knowing the relative heights of the gage above the dam and of the one below the gates in the feeder. The difference between these two readings gives the head on the gate. The stem of the gates is marked so that the

amount of openings at any time can be determined. Readings of the two gages and the two gate stems are made twice a day by Frank Baker.

Estimated daily discharge in second-feet of Oriskany Creek at Oriskany, New York, for 1899.

[Drainage area, 144 square miles.]

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	90	(a)	206	83	180	320	90
2	80	(a)	206	87	138	175	108
3	80	(a)	167	73	108	115	73
4	80	(a)	126	10	99	138	108
5	80	(a)	126	75	119	144	80
6	80	138	177	108	132	346	107
7	80	184	177	101	122	374	99
8	80	170	195	133	138	439	40
9	80	104	195	176	95	364	30
10	80	100	195	180	58	394	10
11	89	117	195	159	106	634	45
12	94	124	195	95	97	534	340
13	89	124	195	73	98	564	330
14	94	124	195	57	26	584	80
15	104	124	206	85	72	564	65
16	101	206	206	89	45	484	80
17	94	206	206	115	106	524	40
18	113	197	206	123	58	564	65
19	113	183	206	119	71	202	250
20	113	183	206	138	48	53	130
21	113	270	206	161	82	124	110
22	113	270	206	129	78	154	50
23	118	270	206	162	85	174	50
24	118	196	206	102	88	214	70
25	118	196	206	112	70	174	50
26	118	196	194	181	70	438	40
27	118	196	184	222	54	318	30
28	113	196	184	216	158	318	35
29	113	196	184	185	72	562	30
30	113	196	96	206	55	789	65
31	.....	196	96	.....	115	.....	70
Mean	99	180	186	126	91	380	89

a No record July 1 to 5.

SAUQUOIT CREEK AT NEW YORK MILLS, NEW YORK.

This creek rises in Oneida County, New York, and flows in a northerly direction, emptying into Mohawk River. It is shown in a part of its course on the Oriskany topographic sheet of the United States Geological Survey. Observations of flow are made on this creek at New York Mills, at which point the creek has a drainage area of 52 square miles. One gage is located at the dam, which furnishes power for mill No. 3, and is read by E. D. Cronk. A gage in the headrace near the mill wheels and one in the tailrace, are read by Robert Hughes. The first gage gives the head on crest of weir, and the two located at the mill give the head on wheels. The quantity flowing through the wheels is added to the flow over the dam to give the total flow of the creek. The dam is of earth, with plank facing, and there is little leakage. For a cross section of this dam see Mr. Rafter's paper on "Flow of water over dams." The profile of the crest of the dam is somewhat irregular, and in order to facilitate computation has been divided into nine parts. Each part is assumed to have a horizontal crest line.

The flow over each part has been computed separately for various heads and a curve drawn showing the relation of the total quantity flowing over the dam to various gage heights. From this curve the total quantity for each head can be read off at once without making a separate computation for each part of the dam. The flow over sections *A* to *E*, inclusive, in this dam was computed by using the coefficients determined by Bazin's experiments of 1895, series No. 175, with $q=8.025mLH^{\frac{3}{2}}$. The flow over sections *F* and *G*, which is over flashboards, was computed from Francis's formula for sharp-crested weirs, with $q=3.33LH^{\frac{3}{2}}$. In the mill there are two 27-inch Hercules turbines, and records are made of the head on wheels and the opening of the gates twice each day. These turbines were rated by the Holyoke Power Company, so that by noting the head and the gate openings the quantity of water passing through the wheels can be computed.

Estimated daily discharge, in second-feet, of Sauquoit Creek at New York Mills, New York, for 1899.

[Drainage area, 52 square miles.]

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	42	12	17	18	0	53	19
2	34	.....	11	5	29	42	13
3	18	27	43	0	24	21	23
4	30	10	30	0	21	26	32
5	42	30	12	33	15	29	22
6	56	27	0	32	16	32	26
7	48	18	26	6	8	32	26
8	39	16	25	21	13	24	19
9	23	25	22	12	18	24	12
10	34	31	0	0	18	19	14
11	31	30	25	22	18	29	16
12	28	27	14	19	18	29	72
13	20	19	0	19	16	29	64
14	19	22	25	8	7	24	38
15	30	13	22	5	13	24	32
16	34	30	18	15	18	21	35
17	38	23	5	0	15	24	35
18	34	27	18	19	16	21	38
19	30	27	5	19	18	24	32
20	30	19	0	13	14	26	42
21	23	11	22	14	12	26	54
22	21	3	19	21	18	26	35
23	25	0	16	10	24	25	32
24	23	27	5	0	18	21	30
25	24	30	15	22	22	18	25
26	26	22	10	15	19	22	32
27	20	27	0	22	15	24	28
28	19	11	22	13	7	24	16
29	20	14	30	18	19	21	19
30	21	0	18	10	32	21	13
31	.....	27	5	.....	26	.....	14
Mean	29	20	15	14	17	26	29

WEST CANADA CREEK AT MIDDLEVILLE, NEW YORK.

This creek rises in the southwestern part of Hamilton County, New York, and flows in a southwesterly direction through Herkimer County, emptying into Mohawk River. It has considerable fall throughout its length, with chances of water-power development. Measurements of flow have been made at Middleville, at the dam of the Nelson Knitting Company. The drainage area of West Canada

Creek at this point is 519 square miles. There is a gage located just above the dam which gives the depth of water on crest; also a gage in the headrace and one in the tailrace of the Nelson Knitting Mill. There are also gages in the tailraces of the gristmill and planing mill located below on the same headrace. By these gages the flow is determined over the dam, through the wheels of the Nelson Knitting Company's mill, and at the gristmill and planing mill. The dam is of timber, with very little leakage. In the Nelson Knitting Mill is one 66-inch standard Leffel turbine, in the planing mill one 24-inch Rochester turbine, in the sawmill one 28-inch Chase turbine, and in the gristmill one 36-inch Camden turbine. Observations of the height and amount of gate opening of these wheels are made twice a day by E. J. Nelson. Near the center of the dam there is an ice slide 56 feet in length. The profile of the crest is nearly horizontal except at the ice slide. The flow over this dam is computed from Bazin's experiments of December, 1895, series No. 170. The experimental section of weir corresponding to the Rexford Flats dam agrees more closely to the form of the Middleville dam than the experimental weir used by Bazin. A revised discharge curve has been drawn, using the coefficients as found in the Cornell University experiment No. 15, corresponding to the Rexford Flats dam. For a cross section of this dam see Mr. Rafter's paper "On flow of water over dams."[1]

Estimated daily discharge in second-feet of West Canada Creek at Middleville, New York, for 1899.

[Drainage area 519 square miles.]

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1,114	198	273	257	480	1,261	330
2	763	140	292	191	510	2,367	580
3	593	200	345	145	470	1,744	710
4	550	116	316	145	436	1,199	710
5	531	240	237	210	337	1,040	518
6	480	240	155	205	253	831	540
7	294	256	296	195	288	469	1,750
8	314	204	262	219	190	542	1,670
9	258	675	256	169	232	482	840
10	182	293	242	145	220	390	700
11	130	807	246	188	214	420	640
12	283	443	214	201	210	410	3,150
13	297	445	125	221	239	342	4,710
14	248	343	254	205	219	313	2,530
15	753	236	246	204	140	372	740
16	839	430	253	189	241	343	840
17	499	600	239	145	238	363	640
18	320	560	235	197	235	372	1,060
19	339	479	174	208	217	220	1,880
20	331	345	110	213	152	337	3,520
21	373	327	226	239	261	310	2,530
22	346	225	245	238	190	363	1,400
23	263	140	257	204	245	293	990
24	213	241	229	145	225	273	1,150
25	155	241	254	209	238	273	900
26	283	241	183	476	231	249	840
27	273	244	110	433	267	312	580
28	280	239	255	248	224	292	540
29	308	171	247	213	965	310	640
30	275	115	262	386	1,040	310	540
31	.....	284	269	.....	629	.....	860
Mean	397	324	235	221	324	577	1,259

[1] Proc. Am. Soc. Civ. Eng., March, 1900, Vol. XXVI, No. 3, p. 315.

MOHAWK RIVER AT LITTLE FALLS, NEW YORK.

The second point of measurement of Mohawk River was at Little Falls, where the drainage area of the Mohawk River is 1,306 square miles. There is at this point a stone dam which furnishes power for the Astronga Knitting Mill and the Little Falls Paper Company's mill. The gage in the headrace of the Astronga Knitting Mill gives the height on the crest of the dam and with the gage in the tailrace gives the head on the wheels. These two gages are read by J. J. Gilbert. There is a gage in the headrace and one in the tailrace of the Little Falls Paper Company's mill, giving the head on the wheels. Record of these gages is kept by William Hoffman. The dam varies somewhat in section from one side of the river to the other. The crest of the dam is horizontal and is divided into two parts to facilitate computation, on account of the variation in sections. The flow over section *A* was computed from Bazin's experiments of July, 1887, No. 117; and that over section *B*, from Bazin's experiments of June, 1894, series No. 135. A revised discharge curve was later used, based upon Cornell experiments Nos. 16 and 17. In the Astronga Knitting Mill there is installed one 43-inch and one 54-inch T. H. Risdon & Co.'s turbine; and in the Little Falls Paper Company's mill one 60-inch Camden, one 36-inch Camden, and one 42-inch Camden, also one 60-inch wheel built by M. Reddy. Records are kept of the flow through all of these wheels whenever running.

Estimated daily discharge, in second-feet, of Mohawk River at Little Falls, New York, for 1899.

[Drainage area, 1,306 square miles.]

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1,957	569	506	278	704	2,829	1,425
2	1,610	493	506	271	651	6,600	1,130
3	1,321	359	135	30	651	4,738	1,950
4	1,075	424	136	396	491	3,081	1,475
5	1,466	490	166	545	534	3,282	1,425
6	1,216	663	0	382	399	2,847	1,000
7	1,016	627	133	272	240	1,908	800
8	1,062	651	131	275	160	1,718	920
9	962	1,660	131	211	357	1,628	1,050
10	764	2,593	130	7	297	1,451	7,000
11	1,176	1,800	316	273	274	717	2,075
12	660	1,320	383	270	305	1,112	5,950
13	660	1,222	0	270	274	1,526	10,300
14	685	941	329	211	258	1,448	7,750
15	960	884	352	230	196	1,150	6,650
16	1,860	643	351	184	354	1,069	2,875
17	1,800	1,315	244	55	339	1,120	1,280
18	965	1,211	251	278	344	1,037	1,000
19	568	1,086	216	267	339	984	4,130
20	1,010	1,008	65	281	355	1,070	7,850
21	1,105	767	158	220	331	1,120	6,500
22	985	95	223	249	142	1,145	5,120
23	866	363	235	129	350	1,066	4,450
24	745	496	203	55	401	987	1,575
25	851	496	203	238	392	900	1,525
26	759	516	246	225	369	829	1,175
27	634	496	136	556	387	822	875
28	585	510	348	920	314	969	950
29	560	460	188	642	1,398	969	700
30	535	50	219	723	2,293	886	450
31	.....	697	277	.....	1,882	.....	380
Mean	1,014	803	223	298	509	1,700	2,959

EAST CANADA CREEK AT DOLGEVILLE, NEW YORK.

This creek rises in Hamilton County, New York, and flows in a southerly direction between Fulton and Herkimer counties into Mohawk River. Observations are taken on this creek at Dolgeville, about 7 miles from its junction with the Mohawk, reached from Little Falls by a branch of the New York Central Railroad. The station is located at the stone dam, which furnishes power for the Dolgeville Electric Light Company. The dam is about 19 feet high, of solid stone masonry, and the water impounded is conducted from the dam to the power house, a distance of about 500 feet, through a wrought-iron flume 10 feet in diameter. A gage located on the abutment of the dam and one in the tailrace of the power house are read twice each day by Henry Meyer, who is employed in the power house. The crest of the dam is horizontal, and flow over it is computed from Bazin's experiments of July, 1887, series No. 117. Experiments known as No. 13 were carried on at Cornell University to determine coefficients of flow over a weir of similar form. In the power house there are installed three Smith-Vaile Victor wheels; two of them 36 inch and one 15 inch. Records are kept of the daily head on these wheels and the amount of gate openings.

Estimated daily discharge in second-feet of East Canada Creek at Dolgeville, New York, for 1899.

[Drainage area 256 square miles.]

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	390	145	165	108	70	1,000	175
2	320	100	225	178	165	1,560	310
3	240	148	240	178	150	840	330
4	.....	94	180	99	150	710	400
5	.....	150	135	128	145	480	310
6	.....	150	99	118	140	520	260
7	220	170	165	113	140	410	190
8	260	230	160	108	130	390	190
9	220	309	160	75	120	360	190
10	220	383	160	108	140	340	200
11	238	283	170	108	130	310	230
12	220	213	180	120	125	110	1,850
13	220	213	50	108	120	280	2,820
14	230	213	40	108	120	260	1,420
15	280	195	20	108	150	260	1,040
16	270	204	125	108	120	310	880
17	192	380	30	108	125	230	710
18	154	280	125	108	160	260	1,240
19	180	210	40	108	150	150	1,590
20	200	170	40	125	155	280	610
21	300	165	120	125	150	240	1,330
22	230	135	120	120	115	220	840
23	210	99	120	120	125	220	740
24	162	145	130	120	150	220	490
25	134	165	140	120	145	190	390
26	190	175	120	225	145	180	240
27	190	160	40	225	140	180	360
28	180	175	120	180	140	180	310.
29	160	165	120	170	300	180	310
30	160	.....	120	190	380	180	280
31	.....	155	120	.....	262	.....	160
Mean	221	196	122	127	153	367	658

GAROGA CREEK AT FORT PLAIN, NEW YORK.

This stream rises in Fulton County, New York, and flows in a southwesterly direction into Mohawk River. Observations for the computation of flow have been taken at Levi Yoran's mill, at Fort Plain. The dam here located is of wood and fairly tight. Gages were read above the dam, giving the height on crest, and in the tailrace of the mill. The water is conducted from the creek above the dam through the mill by a 4-foot circular flume laid underground. The flow over this dam is computed from Bazin's experiments of July, 1894, series No. 130, with $q=8.025mLH^{\frac{3}{2}}$. Experiments were afterwards conducted at Cornell University, from which new coefficients were determined and a revised discharge curve plotted. In the mill there is installed one 28-inch and one 11-inch Lesner turbine, made at Fultonville, New York. These wheels were seldom used, but when they were run careful records were kept of the head and gate openings, so that the quantity passing through the wheels added to the flow over the dam would give the total flow of the creek. On May 30, 1899, observations at this station were discontinued.

CAYADUTTA CREEK AT JOHNSTOWN, NEW YORK.

This creek rises in Fulton County, New York, and flows in a southerly direction into Mohawk River near Fonda. Observations are made at the dam of the Johnstown Electric Light and Power Company, 1 mile below Johnstown, the record being kept by E. Shook, superintendent. The dam is 33 feet high, is built of timber, and has very little leakage. The impounded water is carried from above the dam to the wheelhouse through a 5-foot circular wooden flume. Gages are read above the dam, giving the height on crest, and in the tailrace, which show the head on wheels. The profile of the crest is somewhat irregular, and to facilitate computation has been divided into four parts, the crest lines of each part being assumed horizontal. The flow over section *C*, which is the regular spillway, is computed from Bazin's experiments of July, 1894, series No. 130, with $q=8.025mLH^{\frac{3}{2}}$. The flow over sections *A*, *B*, and *D*, which are the bulkheads, is computed from Bazin's experiments of July, 1887, series No. 115. Experiments upon sections which are considered to correspond more closely with the conditions at Johnstown were carried on at Cornell University, and a revised discharge curve derived, using the coefficients determined by the Cornell experiments. In the computation for the revised discharge curve the coefficients derived from experiment No. 12, corresponding to Bazin's experiment No. 115, were used for sections *A*, *B*, and *D;* and those determined by experiment No. 2, corresponding to Bazin's series No. 135, were used for section *C*.

For a cross section of this dam see Mr. Rafter's paper "On flow of water over dams."[1]

Estimated daily discharge in second-feet of Cayadutta Creek at Johnstown, New York, for 1899.

[Drainage area, 40 square miles.]

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	30	21	20	16	12	33	19
2	28	15	22	20	24	31	------
3	29	24	32	12	24	28	14
4	17	17	22	19	25	48	37
5	29	20	21	28	17	34	27
6	28	20	11	16	15	26	23
7	18	19	19	23	19	23	23
8	30	34	20	22	9	26	23
9	21	16	20	17	18	22	23
10	19	27	20	7	20	27	13
11	18	25	17	16	24	26	27
12	30	18	23	19	23	20	238
13	25	18	8	20	13	23	207
14	24	16	20	17	20	23	145
15	25	18	20	19	17	30	55
16	25	13	20	20	24	20	40
17	25	23	20	11	26	21	44
18	17	25	20	19	33	20	36
19	26	26	19	20	21	6	51
20	37	20	9	21	(a)	27	85
21	32	19	15	20	(a)	27	62
22	33	23	16	17	(a)	26	43
23	32	8	14	19	(a)	25	26
24	32	18	16	14	21	24	19
25	18	22	16	20	18	26	56
26	29	19	14	32	18	14	60
27	26	16	11	36	19	30	25
28	30	17	15	26	16	28	24
29	30	17	16	27	30	28	20
30	22	14	16	26	30	15	19
31	------	25	16	------	------	------	11
Mean	26	20	18	20	21	26	49

a Repairing dam; water drawn off October 20 to 23.

SCHOHARIE CREEK AT FORT HUNTER, NEW YORK.

Schoharie Creek rises in Green County, New York, and flows in a northerly direction through Schoharie and Montgomery counties, and empties into Mohawk River near Tribes Hill Station. Observations for the computation of flow are made on this creek at the State dam, which impounds water for the feeder of the Erie Canal at Fort Hunter. The dam is of timber and practically free from leakage. The profile of the crest of the dam is somewhat irregular, and to facilitate computation is divided into six parts, each part being assumed horizontal. The value of the coefficients of flow over this dam has been obtained by taking the mean of the coefficients for series Nos. 117 and 141 of Bazin's experiments. Cornell experiments No. 114, performed upon the section corresponding to the Rexford Flats dam, was considered to conform more closely to the conditions at Fort Hunter than the sections used by Bazin, and a revised discharge curve was drawn,

[1] Proc. Am. Soc. Civ. Eng., March, 1900, Vol. XXVI, No. 3, p. 316.

using the Cornell coefficients.[1] A measurement of Schoharie Creek was made near the village of Schoharie, New York, by students of the Summer School of Surveying of the Massachusetts Institute of Technology in June, 1889, under the direction of Prof. George F. Swain. Measurement was made by means of a Fteley meter. The results showed a discharge of 972 second-feet.

Estimated daily discharge in second-feet of Schoharie Creek at Fort Hunter, New York, for 1899.

[Drainage area 947 square miles.]

Day.	June.	July. *a*	Aug. *a*	Sept. *a*	Oct.	Nov.	Dec.
1	495	.....	.....	.....	4,147	1,215	661
2	495	.....	.....	.....	2,247	1,895	661
3	595	.....	.....	.....	2,047	1,795	711
4	595	.....	.....	.....	2,527	1,215	761
5	495	.....	.....	.....	2,747	1,215	841
6	495	.....	.....	.....	2,247	1,045	841
7	495	.....	.....	.....	2,047	1,215	786
8	425	.....	.....	.....	1,827	1,215	786
9	405	.....	.....	.....	2,047	1,065	841
10	395	.....	.....	.....	1,247	1,045	786
11	395	.....	.....	.....	1,247	1,215	841
12	395	.....	.....	.....	1,827	1,895	786
13	395	.....	.....	.....	1,827	2,115	881
14	395	.....	.....	.....	2,247	1,795	961
15	395	.....	.....	.....	1,827	1,795	1,111
16	395	.....	.....	.....	2,527	1,215	1,181
17	395	.....	.....	.....	1,247	1,215	1,051
18	395	.....	.....	.....	1,077	1,046	1,111
19	395	.....	.....	.....	867	1,045	1,261
20	395	.....	.....	.....	1,247	1,045	1,111
21	395	.....	.....	.....	1,077	915	1,261
22	395	.....	.....	.....	867	915	1,261
23	395	.....	.....	.....	1,247	735	1,261
24	395	.....	.....	.....	1,077	735	1,111
25	395	.....	.....	.....	2,247	795	1,051
26	395	.....	.....	.....	2,047	735	1,051
27	395	.....	.....	.....	2,427	705	961
28	395	.....	.....	.....	1,827	615	961
29	395	.....	.....	.....	2,247	615	1,261
30	395	.....	.....	.....	2,427	575	1,261
31	.....	.....	.....	.....	1,827	.....	1,261
Mean	413	.....	.....	.....	1,880	1,155	989

a Data not sufficient to compute record for July, August, and September

MOHAWK RIVER AT SCHENECTADY, NEW YORK.

A few measurements of the flow of Mohawk River have been made at Freeman's toll bridge, about one-fourth of a mile above the Delaware and Hudson Canal Company's railroad bridge and about 1 mile below the New York Central and Hudson River Railroad bridge. A temporary station was established here on January 28, 1899, and maintained until September 30, 1899, by Prof. Elton D. Walker, of Union College, Schenectady, New York. The observer is Mrs. J. Diggin. The equipment consists of a wire gage with a 4-pound iron sash weight and galvanized line. The graduated rod is fastened to the guard rail on the upstream side of the northwest section of the

[1] On flow of water over dams, by George W. Rafter: Proc. Am. Soc. Civ. Eng., March, 1900, Vol. XXVI, No. 3, p. 317.

bridge and is marked in tenths of a foot from zero to 17 feet. There is a bench mark on the upstream end of the top of the capstone on the pier nearest the northwest or right bank of the river. A second bench mark is the southerly corner of the top of the masonry bridge seat on the upstream end of the northwest abutment. Both bench marks are 23.96 feet above the zero of the gage. The initial point for soundings is the face of the bridge seat on the upstream end of the southeast abutment. The channel is approximately straight and of uniform width for 600 feet above and half a mile below the site. The section is obstructed by three piers and crib foundations, but is otherwise good. The swiftest current is through the southeast span. The right bank is low and liable to overflow, but the road running to the northwest prevents the overflow passing around the bridge except in unusually high freshets. The left bank is high, being the tow-path of the Erie Canal, and is not liable to overflow except in extremely high freshets occurring at the time of an ice jam in the river below. Measurements are made from the upstream side of the bridge. The three following discharge measurements were made during 1899 by Prof. E. D. Walker: April 3, gage height 7.18 feet, discharge 5,298 second-feet; May 26, gage height 6.22 feet, discharge 2,092 second-feet; June 30, gage height 5.38 feet, discharge 482 second-feet.

Daily gage height in feet of Mohawk River at Schenectady, New York, for 1899.

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.
1	6.60	8.15	7.45	8.60	(a)	5.33	5.20	5.10
2	6.30	8.05	7.60	8.45	(a)	5.30	5.18	5.17
3	6.10	7.50	7.40	8.75	(a)	5.30	5.35	5.15
4	6.10	7.20	7.10	7.95	(a)	5.30	5.35	5.17
5	6.10	8.00	7.80	7.40	(a)	5.23	5.40	5.20
6	6.70	13.80	8.43	7.00	(a)	5.23	5.38	5.18
7	6.10	10.93	9.53	6.70	(a)	5.22	5.20	5.15
8	6.10	9.00	10.15	6.55	5.50	5.30	5.20	5.20
9	6.20	8.80	11.13	6.45	5.45	5.33	5.15	5.20
10	6.30	8.20	9.80	6.25	5.43	5.78	5.15	5.12
11	6.10	7.85	9.30	6.20	5.40	6.10	5.15	5.10
12	5.90	7.65	10.90	6.20	5.38	5.98	5.18	5.10
13	5.90	11.84	11.80	6.45	5.30	5.70	5.20	5.08
14	5.90	10.15	12.98	6.50	5.28	5.50	5.20	5.05
15	5.95	9.40	13.50	6.60	5.33	5.48	5.15	5.05
16	6.00	8.70	12.88	6.55	5.30	5.45	5.12	5.05
17	6.00	8.60	11.55	6.40	5.70	5.40	5.10	5.00
18	6.00	7.70	11.25	6.58	5.72	5.70	5.12	5.03
19	6.00	7.30	11.20	6.80	5.53	5.68	5.05	5.00
20	6.15	8.40	12.50	6.98	5.43	5.55	5.12	5.10
21	6.30	8.50	11.55	7.35	5.45	5.45	5.10	5.10
22	6.85	7.90	11.10	7.25	5.90	5.45	5.08	5.10
23	8.85	7.65	10.70	6.95	5.55	5.30	5.05	5.10
24	8.84	7.75	10.60	6.58	5.45	5.25	5.10	5.10
25	8.00	7.95	10.60	6.35	5.40	5.23	5.10	5.08
26	7.70	7.70	10.45	6.22	5.40	5.20	5.08	5.53
27	7.35	7.80	10.40	6.10	5.38	5.20	5.10	6.05
28	8.10	7.25	10.00	6.05	5.33	5.20	5.12	6.35
29	.....	7.10	9.45	6.20	5.38	5.20	5.05	5.90
30	.....	7.75	8.85	6.70	5.35	5.32	5.10	5.75
31	.....	7.23	.....	7.00	.....	5.15	5.10	(b)

a Repairing bridge. b Discontinued September 30.

MOHAWK RIVER AT REXFORD FLATS, NEW YORK.

Observations of river height are made at Rexford Flats, 4 miles below Schenectady, for the computation of flow of Mohawk River. This is a State dam, built of solid masonry, with a timber apron, and furnishes water for the feeder of the Erie Canal. Gages are read showing the height on crest of the dam and the head on the feeder gate, so that the amount of water flowing over the dam into the feeder can be determined. The profile of the crest of the dam is irregular, and to facilitate computation has been divided into five sections. The value of the coefficients for any depth on the crest of this dam has been obtained by taking the mean of the corresponding coefficients for series Nos. 117 and 141 of Bazin's experiments. Experiments were carried on at Cornell University to determine the coefficients of flow over an experimental weir of the exact form of the one located at Rexford Flats. This was known as "Cornell experiment No. 14." A revised discharge curve was computed, using the coefficients as determined by these experiments. H. R. Betts is the observer at this station. In comparing the results obtained at Little Falls and Rexford Flats, Mr. Robert E. Horton, who has made the computations, states that he has not been able to reconcile them, the former appearing to be the more accurate and the latter too small in proportion. For a cross section of this dam see the paper "On flow of water over dams," by George W. Rafter: Proc. Am. Soc. Civ. Eng., March, 1900, p. 312.

Daily discharge in second-feet of Mohawk River at Rexford Flats, New York, for 1899.

[Drainage area, 3,385 square miles.]

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2,288	928	328	228	2,728	1,968	1,328
2	2,288	928	328	228	2,928	1,968	1,328
3	2,078	679	438	228	2,928	2,928	3,206
4	2,078	608	498	228	2,628	5,028	2,448
5	2,078	608	528	228	2,628	6,528	2,628
6	1,538	608	608	228	2,628	6,528	2,908
7	1,538	438	328	228	2,478	8,028	3,578
8	1,538	438	278	228	2,328	9,028	4,548
9	1,378	608	278	228	2,178	7,928	6,078
10	1,378	528	278	228	1,428	4,928	8,328
11	1,128	438	278	228	728	2,778	8,958
12	1,128	438	278	228	728	2,178	10,028
13	928	378	278	228	728	1,578	10,828
14	928	328	278	228	728	1,928	15,828
15	1,038	328	278	238	1,228	2,078	21,358
16	1,038	328	278	278	1,578	1,578	24,228
17	2,928	758	278	278	1,828	1,968	19,128
18	3,528	928	278	278	1,928	1,968	13,128
19	4,628	678	278	278	1,428	1,128	8,128
20	5,128	678	228	278	1,348	1,128	10,228
21	2,628	438	228	278	1,348	1,228	6,328
22	3,228	328	228	278	1,348	1,478	4,928
23	2,168	328	228	278	1,228	1,578	4,578
24	2,168	308	228	278	1,148	1,578	4,578
25	2,078	288	228	278	1,128	1,968	2,428
26	1,538	288	278	3,228	1,028	1,968	2,928
27	1,538	328	278	9,178	828	1,128	2,928
28	1,538	438	238	6,328	728	1,128	2,828
29	1,428	328	208	1,678	1,228	1,128	2,628
30	1,538	378	208	2,778	1,348	1,968	2,428
31	.....	338	208	.....	1,348	.....	2,228
Mean..	2,014	498	294	980	1,608	2,824	7,001

SCHROON RIVER AT WARRENSBURG, NEW YORK.

This river rises in Essex County, along the southern slopes of the highest mountains in the Atlantic group, and flows in a general southerly direction for about 45 miles, until it joins Hudson River, as described in Water-Supply Paper No. 24, page 43. There are no developed water powers excepting that at Warrensburg, near the mouth. At this point records of river height have been kept by J. Goodfellow, the superintendent of the Schroon River Pulp Company, The dam at this point was built in 1893, and is said to be as tight as any of its kind. The observations were begun in 1895, the gages being established by Mr. George W. Rafter in connection with his investigations of the Upper Hudson storage surveys, in progress at that time. Mr. Wallace Greenalch, as assistant to Mr. Rafter, computed the flow of the river, but in his opinion these computations were to a certain extent vitiated by the possible leakage through the dam and complications introduced by flashboards being continually changed.

HUDSON RIVER AT FORT EDWARD, NEW YORK.

This river, as a whole, has been described in Water-Supply Papers Nos. 24 and 25. Estimates of flow have been made at two points, the upper at Fort Edward, about halfway between the mouth of Schroon River and Albany, and the lower at Mechanicville, above the mouth of Mohawk River. Records are being kept of the height of water surface above the crest of the dam at Fort Edward by the International Paper Company, B. A. Carr, superintendent. The estimated discharge was computed at the office of the State engineer and surveyor, but without taking the modifications introduced by the flashboards into account. The data were later placed in the hands of Mr. Robert E. Horton, but he has had opportunity to compute the flow during only one or two months. There is a peculiarity in regard to the method of reading the gage, but otherwise the results are satisfactory and worthy of computation.

HUDSON RIVER AT MECHANICVILLE, NEW YORK.

A daily record of the height of water passing over the dam of the Duncan Company, at Mechanicville, New York, has been kept, with few omissions, since 1887, as described in the report prepared by George W. Rafter.[1] These observations are made twice daily, at 7 a. m. and at 4 p. m., except Sundays, when the afternoon observations are omitted. The depth of the water on the crest of the dam is measured at a point sufficiently removed from the crest not to be influenced by the curve of the water surface. Besides these readings,

[1] Water-Supply and Irrigation Paper No. 24, page 78.

the difference in elevation between the surface of the water at the entrance and discharge from the water wheels is noted. The flow, as stated by R. P. Bloss, the engineer of the Duncan Company, is obtained by the use of Francis's formula for weirs with wide crests: $q=3\ LH^{\frac{3}{2}}$, in which q is the discharge in cubic feet per second, H the head in feet on crest of the dam, and L the length of the dam, which, in this case, is 794 feet. The coefficient used (3) was determined for dam of similar cross section. When the water wheels are in operation the head on wheels is determined by observation, and the amount of water used on each wheel under the given head is taken directly from the table given by the water-wheel builder. There being no leakage of the dam or canal the sum of the flow over the dam and the flow through the wheels gives the total flow of the river at the time of the observation.

Daily discharge in second-feet of Hudson River at Mechanicville, New York.

[Drainage area, 4,500 square miles.]

1896.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	24,147	3,177	22,189	21,647	9,050	6,627	2,324	2,374	2,077	2,991	3,494	13,028
2	22,847	3,289	32,900	20,147	7,252	6,027	2,324	2,736	1,770	3,441	3,652	11,650
3	19,547	3,402	27,525	18,947	7,027	6,027	2,234	3,099	1,770	3,916	3,382	8,200
4	15,627	3,402	25,880	16,097	6,802	4,752	2,324	2,949	1,770	4,016	3,332	7,200
5	11,652	3,527	26,230	14,774	6,202	4,477	2,324	2,674	1,770	4,116	3,652	7,450
6	7,677	3,477	18,122	13,452	6,202	4,477	2,324	2,324	3,055	3,841	23,335	7,575
7	5,677	13,327	17,247	14,327	5,677	4,389	2,999	2,324	4,341	3,666	25,735	7,700
8	5,602	7,427	16,822	13,127	5,402	4,302	2,724	2,324	3,816	3,916	24,235	6,353
9	5,677	6,302	16,397	13,127	4,902	5,277	2,799	2,412	2,916	3,916	22,735	7,850
10	5,602	5,177	14,247	13,677	5,002	6,227	2,774	2,499	2,791	3,441	19,085	11,498
11	5,377	5,177	11,837	13,827	5,102	8,127	2,774	2,449	2,616	3,678	16,985	10,922
12	5,189	4,377	8,502	15,708	4,477	7,927	2,624	2,399	2,541	3,916	15,735	10,067
13	4,902	4,202	7,827	17,589	4,527	6,027	2,474	2,424	2,441	3,391	14,185	9,259
14	4,902	4,027	7,127	25,314	3,802	6,127	2,624	2,399	2,341	3,791	12,680	8,450
15	4,702	4,377	6,789	34,414	3,602	6,227	2,324	2,374	2,491	7,416	11,582	7,950
16	4,302	3,864	6,452	39,775	3,877	5,677	2,324	2,324	2,491	6,766	10,485	6,253
17	4,152	3,352	6,027	48,300	3,877	6,127	2,324	2,394	2,291	5,741	10,680	9,125
18	3,877	3,677	5,602	55,400	3,877	4,677	2,324	2,424	2,241	5,278	9,635	6,750
19	4,127	4,077	5,677	59,393	3,352	4,152	2,324	2,499	2,266	4,816	8,380	5,350
20	4,377	4,152	15,702	52,050	3,227	4,077	2,324	2,474	3,503	4,366	7,635	5,138
21	4,152	3,752	11,977	45,400	3,227	4,139	2,949	2,394	4,741	4,016	6,985	4,925
22	4,027	3,677	10,077	37,496	2,977	4,202	4,324	2,374	4,991	4,541	7,025	4,300
23	3,952	3,739	8,177	32,314	2,952	3,177	5,349	2,361	4,116	4,166	7,085	4,400
24	3,677	3,802	6,102	26,230	3,052	3,002	4,774	2,349	3,716	4,166	6,585	3,435
25	3,802	3,952	6,302	21,672	3,152	2,777	3,424	2,374	3,666	4,141	6,385	3,918
26	3,877	3,802	7,877	18,349	2,977	2,677	3,074	2,324	2,991	4,116	9,185	4,400
27	3,952	3,677	13,997	15,027	3,152	2,427	2,724	2,324	2,991	3,116	10,485	4,350
28	3,527	3,677	9,177	12,102	3,527	2,489	2,449	2,324	2,991	2,916	11,535	4,300
29	3,277	11,477	12,787	10,077	3,802	2,552	2,349	2,324	2,791	3,116	12,110	3,675
30	3,177	.....	16,397	9,477	5,027	2,377	2,474	2,324	2,866	3,241	12,685	3,950
31	3,177	.....	20,147	.....	5,827	.....	2,374	2,324	.....	3,316	.....	4,300
Mean	6,791	4,668	13,600	24,972	4,610	4,738	2,772	2,442	2,879	4,106	11,352	6,913

Daily discharge in second-feet of Hudson River at Mechanicville, New York—Continued.

1897.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4,110	3,595	3,000	13,028	13,950	9,300	5,950	14,290	4,000	2,290	2,150	17,121
2	4,550	3,300	2,664	12,906	13,100	8,400	5,050	13,650	3,800	2,245	3,475	15,655
3	4,485	3,675	3,065	13,028	12,250	6,830	4,500	11,810	3,295	3,065	10,550	13,539
4	4,420	4,512	11,193	13,789	12,114	11,950	4,500	11,650	3,295	2,290	10,149	11,466
5	4,300	3,300	7,050	14,550	12,728	13,950	4,500	9,450	3,033	2,170	8,817	13,509
6	6,623	4,230	13,950	18,670	12,250	12,425	4,500	8,825	2,770	2,150	7,314	20,531
7	5,600	6,346	11,225	21,450	13,150	10,900	3,932	7,400	2,715	2,150	5,915	16,404
8	5,350	8,450	8,500	21,300	11,810	8,725	4,650	6,485	2,664	2,150	5,752	15,435
9	5,185	5,975	8,815	20,750	10,155	10,600	5,430	5,570	2,540	2,150	5,752	14,437
10	5,130	5,350	12,900	23,806	8,500	25,986	4,750	5,150	2,450	3,180	9,266	13,462
11	5,075	4,200	14,550	18,890	8,400	27,188	4,650	6,025	2,340	2,150	9,224	12,927
12	3,880	3,932	14,110	13,973	9,350	24,790	4,550	13,350	2,370	2,150	11,254	13,000
13	3,595	3,180	12,900	15,918	10,450	22,170	6,750	11,350	2,400	2,450	12,243	17,150
14	3,370	3,328	10,925	15,550	22,550	19,550	23,150	9,650	2,664	3,000	13,768	15,559
15	3,300	3,475	8,950	16,940	19,625	17,280	31,060	9,238	2,370	3,135	10,794	31,178
16	3,595	3,180	8,400	22,269	17,188	15,900	22,750	8,825	2,715	3,065	10,000	35,706
17	3,853	3,295	7,150	23,340	14,750	13,150	18,670	9,450	2,450	4,110	13,300	32,515
18	4,110	3,135	6,830	23,908	13,650	11,200	16,390	8,250	2,340	2,664	11,800	29,702
19	3,300	2,930	6,830	24,476	11,500	9,220	14,110	7,550	4,000	2,900	11,620	23,114
20	3,300	2,820	12,900	23,621	12,100	9,220	11,956	7,775	2,290	2,664	10,650	15,379
21	3,300	3,058	15,375	20,950	11,300	9,220	11,193	7,050	2,664	2,370	8,628	12,207
22	3,350	3,295	17,850	19,625	11,810	8,950	11,350	6,500	2,540	2,346	9,354	8,486
23	3,435	4,120	18,470	17,150	10,980	7,025	11,950	5,950	2,180	2,150	8,182	6,900
24	3,555	4,212	23,010	16,941	10,150	7,250	12,230	6,830	2,380	3,070	7,451	4,819
25	3,675	3,135	23,957	19,346	9,300	6,220	11,425	7,775	2,290	2,290	6,368	2,785
26	2,925	3,050	19,950	21,750	10,000	5,820	10,620	7,775	3,930	2,150	7,395	2,293
27	2,875	3,000	17,973	25,200	10,330	5,485	9,450	6,750	2,664	2,150	15,402	4,122
28	3,350	3,000	15,912	22,450	11,650	5,150	8,950	6,025	2,770	2,150	15,848	7,047
29	3,530	.....	13,850	19,017	10,950	4,400	19,550	5,513	2,370	2,150	19,456	6,467
30	3,530	.....	13,028	17,625	10,700	7,400	20,950	5,000	2,380	2,150	16,984	6,467
31	3,563	.....	13,350	.....	10,450	.....	14,930	4,550	.....	3,135	.....	6,467
Mean	4,007	3,895	12,214	19,074	12,167	11,855	11,109	8,241	2,756	2,524	9,995	14,382

1898.

1	5,512	5,235	5,295	20,306	13,474	9,490	3,179	3,005	a4,345	3,222	7,954	6,300
2	4,689	5,095	5,280	18,018	11,545	8,159	3,014	3,888	a4,007	2,877	7,667	6,130
3	5,035	5,272	5,208	15,810	9,702	7,558	3,007	6,225	a4,145	2,835	6,590	5,608
4	5,186	4,151	5,208	13,890	10,820	6,292	3,007	5,722	a4,340	2,780	6,500	5,185
5	5,306	4,353	5,055	11,932	10,570	5,808	3,364	6,031	4,547	11,210	5,890	5,904
6	5,485	6,475	5,200	10,692	11,300	5,508	2,588	5,832	4,145	20,089	5,803	6,500
7	6,626	5,203	5,250	9,928	11,032	4,729	2,453	5,415	4,007	9,472	5,890	6,322
8	7,256	5,000	5,186	8,787	10,250	4,399	2,314	5,091	4,930	8,261	5,503	5,456
9	5,890	4,826	6,819	8,158	9,700	4,249	2,220	4,335	4,217	7,872	5,872	4,150
10	6,168	4,826	7,431	7,924	8,695	3,978	1,163	3,926	3,813	6,960	6,238	4,675
11	5,951	6,325	10,361	7,915	7,875	3,425	2,000	3,743	3,368	6,038	20,256	4,345
12	5,298	10,022	20,994	7,646	8,420	3,857	2,182	3,387	3,304	6,109	16,262	4,290
13	11,499	13,042	27,300	8,553	11,054	4,299	2,058	3,331	3,188	5,331	14,510	3,739
14	10,975	10,425	39,389	9,815	10,585	4,945	2,080	3,148	2,732	4,829	13,202	3,540
15	10,160	9,074	36,375	9,824	10,161	7,662	2,184	3,362	2,597	6,888	11,385	3,850
16	10,647	8,100	32,325	12,188	9,967	6,872	2,159	3,250	2,487	7,838	10,366	4,007
17	9,672	5,682	30,625	12,575	10,082	5,681	1,163	3,223	2,597	8,125	9,722	4,495
18	7,515	7,480	32,325	12,188	10,637	4,620	2,192	3,235	2,873	7,250	8,910	4,590
19	7,008	7,788	29,935	11,155	9,404	4,851	2,224	3,660	2,873	6,500	8,922	4,590
20	7,952	7,571	30,000	11,157	9,412	5,593	2,175	4,507	3,365	6,508	10,505	4,885
21	13,757	8,009	36,235	10,922	8,355	4,603	2,192	4,495	2,975	6,418	11,167	5,035
22	10,170	7,906	34,035	10,127	7,954	4,399	3,188	4,718	2,899	6,310	10,366	5,035
23	9,780	7,258	30,615	9,815	8,000	4,198	3,565	3,927	2,666	6,894	9,610	6,908
24	11,458	6,542	27,450	9,627	8,400	4,348	3,549	5,779	3,297	7,578	8,898	8,369
25	9,436	6,263	24,860	20,440	9,491	4,097	3,928	a11,167	5,231	7,178	8,685	7,747
26	8,628	5,992	21,860	24,210	11,953	4,024	4,565	a9,953	6,878	6,693	7,847	6,885
27	7,788	5,294	19,600	24,338	14,758	4,115	4,258	a8,125	5,706	9,382	6,413	5,872
28	7,719	5,911	19,910	20,440	15,327	3,556	3,656	a8,250	4,775	11,042	5,820	4,618
29	6,624	.....	20,660	18,165	14,140	3,508	3,352	a6,109	4,345	10,485	6,300	4,628
30	5,361	.....	23,560	14,873	12,727	3,238	3,175	a4,829	3,650	10,059	6,300	4,828
31	4,860	.....	22,640	.....	10,490	.....	3,015	a4,217	.....	9,953	.....	5,348
Mean	7,723	6,754	20,225	13,047	10,525	5,069	2,751	5,029	3,810	7,516	8,978	5,291

a Discharge August 25 to September 4, not exact, owing to irregular flashboards.

Daily discharge in second-feet of Hudson River at Mechanicville, New York—Continued.

1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4,262	3,910	7,847	7,980	26,900	3,990	2,220	1,520	1,713	.....	4,564	3,005
2	4,262	4,268	7,040	7,159	27,617	3,796	1,047	629	1,561	4,042	8,889	3,414
3	5,209	4,268	6,403	6,955	25,551	3,601	2,128	1,213	.....	3,453	12,020	3,753
4	6,065	4,150	.....	7,934	22,472	2,220	.....	1,153	1,293	2,850	11,899	5,545
5	9,146	4,002	.....	9,405	19,242	2,990	2,741	1,085	1,860	2,745	10,346	6,678
6	8,460	4,223	16,501	9,955	15,152	2,840	1,610	.....	1,764	2,650	11,049	5,974
7	8,355	4,048	12,206	11,719	12,662	2,728	1,670	1,494	1,706	2,571	9,308	5,210
8	8,350	4,275	9,077	19,708	10,960	2,805	1,211	1,616	1,680	.....	8,140	4,558
9	8,026	3,448	8,665	18,275	9,270	2,525	.....	1,475	1,466	2,596	7,166	3,806
10	6,562	3,665	7,909	15,062	8,587	2,290	3,000	484	.....	2,712	6,662	3,265
11	5,766	3,622	7,315	15,582	7,446	.....	3,533	1,148	1,480	2,903	6,182	3,569
12	5,250	4,062	11,739	16,875	7,550	2,399	3,296	993	1,598	2,874	5,490	4,979
13	5,272	4,196	15,437	17,145	7,155	2,505	3,243	.....	1,471	2,926	6,321	11,183
14	5,960	4,508	12,153	21,378	7,060	2,230	3,002	1,580	1,567	2,353	5,536	14,576
15	7,435	4,600	10,555	27,975	7,772	2,135	2,800	1,680	1,484	.....	5,179	14,979
16	8,910	4,798	10,012	29,730	7,346	3,078	.....	1,501	1,549	2,177	4,858	13,452
17	10,155	5,598	9,080	31,112	5,738	3,060	2,861	1,815	.....	2,132	5,283	9,646
18	9,685	5,691	7,895	29,667	5,729	2,762	3,338	979	711	1,853	4,857	9,534
19	7,339	5,620	9,322	29,711	5,928	2,950	2,860	1,390	1,636	1,798	4,359	9,968
20	6,385	5,267	11,350	33,940	5,917	2,508	2,560	.....	957	1,997	4,838	10,950
21	6,297	4,855	9,670	36,210	5,925	2,372	2,485	1,610	941	2,185	4,729	11,048
22	5,770	5,686	9,337	36,210	6,187	2,280	2,295	1,123	1,448	.....	4,587	10,721
23	5,697	10,083	8,645	37,146	5,313	2,105	.....	1,743	1,464	2,466	4,297	9,642
24	5,522	7,501	8,657	38,283	4,756	1,878	2,240	2,460	.....	2,698	3,964	8,068
25	6,950	5,583	8,095	39,064	4,710	304	2,233	1,383	1,516	2,372	3,731	8,241
26	5,775	5,255	7,492	41,475	4,462	1,878	2,188	1,463	2,116	2,304	3,472	7,821
27	5,438	6,450	6,895	40,064	4,117	2,241	2,021	.....	6,000	2,128	4,027	5,832
28	4,545	10,326	6,615	38,300	3,985	2,290	2,140	1,756	5,127	2,216	3,495	5,435
29	4,290	.....	7,835	33,908	4,125	2,368	1,686	1,738	4,413	.....	3,439	4,889
30	4,345	.....	8,765	30,292	3,787	2,512	.....	1,739	4,870	3,198	3,318	4,075
31	4,066	.....	7,602	.....	3,918	.....	2,055	1,477	.....	3,815	.....	2,585
Mean	6,437	5,141	9,316	24,607	9,591	2,539	2,402	1,417	2,054	2,616	6,066	7,303

SAWKILL RIVER NEAR KINGSTON, NEW YORK.

The Sawkill, a small stream which supplies Kingston, New York, with water, has been measured by Mr. William Rich Hutton, at a point about 4.5 miles above its mouth in Esopus Creek, its discharge being 1.25 second-feet. On two occasions after heavy rains the discharge at the same place has been more than 8,000 second-feet from a drainage area of 35 square miles. This quantity continued a very short time, probably about an hour. The location of this stream is shown on the Kaaterskill topographic sheet. It rises behind Overlook Mountain, flows by the village of Woodstock, and joins the Esopus about 4 miles below the city of Kingston. Reservoir No. 1 is shown on the map, but reservoir No. 2, constructed in 1897, about 1½ miles below Woodstock, is not given.

In April, 1895, the mountains being covered with snow 12 inches deep, there occurred a south wind and light rain for two days followed by twelve hours of very heavy rain. On the evening of April 4 the water in reservoir No. 1 began to rise rapidly, and about 9 p. m. the noise of the floating logs and ice and the rapidly rising water alarmed the gate keeper so that he moved his more important furniture by boat to higher ground. At midnight the water was at its highest and by 8 a. m. on April 5 it was falling rapidly. From the maximum height of water on the spillway it is computed that the outflow of the reservoir was a little less than 8,000 second-feet. In 1896 it is estimated that a similar flood furnished over 8,000 second-feet.

CROTON RIVER.

This stream receives its waters from the drainage area immediately north of the city of New York and east of Hudson River. It flows in a general southerly and westerly course, emptying into the Hudson above Sing Sing. A number of reservoirs have been built within its basin for the water supply of the city of New York, and a new dam is being constructed about 3.2 miles above the mouth, at what is known as the "Cornell site." The location of the river and principal reservoirs is shown on the West Point, Carmel, Tarrytown, and Stamford topographic sheets of the United States Geological Survey. Figures of the yield of this watershed have been prepared by the engineers of the aqueduct commission. The monthly discharges in second-feet for the years 1870 to 1898 have been printed in the Twentieth Annual Report, Part IV, page 83. The following table, obtained from Mr. W. R. Hill, chief engineer, gives a continuation of this for 1899. The figures of rainfall are those obtained at Boyds Corners, in Croton basin.

Rainfall and run-off of Croton River watershed for 1899.

[Drainage area, 338 square miles.]

Month.	Rainfall.	Run-off.	Month.	Rainfall.	Run-off.
	Inches.	*Sec.-feet.*		*Inches.*	*Sec.-feet.*
January	4.38	1,210	August	0.48	114
February	5.07	943	September	8.81	305
March	7.58	2,217	October	1.48	237
April	1.99	1,240	November	2.05	277
May	1.80	344	December	2.75	263
June	5.38	152			
July	5.99	344	The year	47.76	636

The total depth of run-off in inches during 1899 was 25.55, this being 53 per cent of the rainfall, as given in the above table.

DELAWARE RIVER AT LAMBERTVILLE, NEW JERSEY.

This river rises in Delaware County, New York, flows in a southerly direction, forming the boundary between the States of Pennsylvania and New Jersey, and empties into Delaware Bay. Measurements of flow were made in 1891 by Prof. Dwight Porter and students at the Delaware Water Gap, Pennsylvania. The results show a flow of from 2,000 to 2,200 second-feet during the latter half of June, 1891. This was said to be the lowest June stage for five years. Measurements were made during the drought of 1895 by Prof. L. M. Haupt at Point Pleasant, Pennsylvania, near the intake of the Delaware and Raritan Canal feeder. The discharge above the bridge was 1,657 second-feet and below the bridge 1,328 second-feet. Delaware River was measured by E. G. Paul, June 4, 1899, at Martins Creek, Pennsylvania, 7 miles above the mouth of Lehigh River, and a discharge

of 2,724 second-feet was found. Lehigh River was measured on June 5, 1899, by E. G. Paul, at the Glendon Bridge at Easton, Pennsylvania, and was discharging 991 second-feet. Systematic measurements of river height were begun on July 23, 1897, at the covered toll bridge at Lambertville, New Jersey, a town on the Belvidere division of the Pennsylvania Railroad, 16 miles above Trenton. The gage, established by E. G. Paul, consists of a stamped-link brass chain 33 feet long, with a 6-pound sash weight attached. The chain passes over a pulley and the index is referred to a scale painted on a horizontal board 32 feet long, fastened to the studding and inclosed in a wooden cover. The zero of the gage chain is marked by a copper rivet, which is 28.85 feet from the end of the weight, and reads 2 feet when the water is at zero on a gage on the first bridge pier. Measurements are made from the windows of this covered bridge. The initial point for soundings is on the left bank. The channel above and below is nearly straight, the water being sluggish for a short space on the left side. The right bank is high and the bed of the stream is of gravel and sand. The observer is Charles H. Naylor, collector of bridge tolls, Lambertville, New Jersey. Records of measurements may be found as follows: 1897, Nineteenth Annual Report, Part IV, page 122; 1898, Twentieth Annual Report, Part IV, page 85. Three measurements were made during 1899, by E. G. Paul, as follows: March 31, gage height 6.30 feet, discharge 27,737 second-feet; June 2, gage height 3.70 feet, discharge 6,410 second-feet; September 19, gage height 2.75 feet, discharge 2,430 second-feet.

Daily gage height, in feet, of Delaware River at Lambertville, New Jersey, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.95	(a)	6.80	6.25	4.75	3.60	4.40	4.20	3.45	4.65	3.40	3.80
2	(a)	(a)	6.80	6.25	4.60	3.60	4.30	4.00	3.35	4.45	3.80	3.80
3	(a)	(a)	6.30	5.95	4.60	3.30	3.95	4.00	3.35	4.25	4.05	3.80
4	(a)	(a)	6.25	5.80	4.50	3.20	3.75	3.90	3.30	4.10	4.65	3.80
5	5.40	4.50	7.95	5.65	4.40	3.05	3.65	3.85	3.45	4.05	4.75	3.95
6	6.05	4.45	8.30	5.70	4.30	2.90	3.65	3.70	4.90	3.95	4.60	3.85
7	7.00	4.40	9.65	5.90	4.20	2.95	3.65	3.90	4.35	3.90	4.55	3.90
8	6.55	4.40	8.20	7.40	4.10	2.85	3.60	3.65	3.95	3.85	4.35	3.75
9	6.10	(a)	7.20	9.10	4.00	2.90	3.90	3.55	3.85	3.75	3.75	3.75
10	5.80	(a)	6.45	8.70	3.90	2.90	3.80	3.45	3.75	3.70	4.10	3.95
11	5.35	(a)	6.20	7.65	3.85	2.85	3.75	3.65	3.50	3.60	4.10	3.70
12	5.00	(a)	6.30	7.15	4.00	2.70	3.70	3.55	3.90	3.60	4.10	3.75
13	4.80	(a)	7.50	7.75	4.00	2.60	3.75	3.35	3.65	3.60	4.25	4.20
14	4.90	(a)	9.15	8.45	4.00	2.65	3.55	3.15	3.45	3.50	4.50	5.30
15	5.05	(a)	8.10	8.85	3.90	2.60	3.55	3.10	3.35	3.50	4.45	5.60
16	5.40	(a)	7.70	9.00	3.80	2.60	3.45	2.95	3.15	3.40	4.35	5.30
17	5.95	(a)	6.90	8.90	3.80	2.50	3.60	2.80	3.10	3.40	4.35	5.10
18	6.10	(a)	6.45	7.85	3.70	2.60	3.60	2.75	2.85	3.45	4.50	4.85
19	5.50	(a)	7.40	7.25	3.80	2.45	3.70	2.50	2.75	3.40	4.50	4.70
20	5.30	7.60	8.70	7.05	3.90	2.40	3.75	2.80	3.90	3.40	4.45	4.65
21	5.30	6.65	9.00	7.15	3.90	2.40	3.55	2.65	3.90	3.40	4.30	4.75
22	4.95	5.70	8.05	7.00	3.80	2.45	3.50	2.75	3.90	3.45	4.20	4.75
23	5.05	6.05	7.70	6.70	3.70	2.75	3.35	2.90	3.75	3.35	4.20	4.65
24	4.95	5.95	7.35	6.15	3.60	3.00	3.25	2.85	3.70	3.30	4.20	5.10
25	7.30	5.65	7.25	5.95	3.60	3.25	3.10	2.60	3.65	3.25	4.10	5.45
26	6.00	5.45	7.00	5.70	3.50	3.70	3.15	2.75	5.40	3.20	4.00	5.45
27	5.60	8.25	6.65	5.50	3.40	4.30	3.40	3.95	6.05	3.20	4.00	5.20
28	5.25	7.20	6.60	5.40	3.40	4.05	4.15	4.20	6.25	3.20	3.95	5.00
29	4.95	.....	7.40	5.10	3.20	4.00	4.00	3.75	5.40	3.45	3.90	(a)
30	4.95	.....	6.80	4.90	3.20	4.00	3.85	3.55	5.00	3.25	3.90	(a)
31	4.75	.....	6.40	.....	3.40	.....	4.80	3.65	.....	3.20	.....	(a)

a Ice.

TOHICKON CREEK AT POINT PLEASANT, PENNSYLVANIA.

This stream drains an area of 102 square miles in the eastern portion of Pennsylvania and, flowing easterly, discharges into Delaware River about 8 miles above Lambertville, New Jersey. Measurements of the stream were begun in 1885 by Mr. Rudolph Hering, and continued by Mr. John E. Codman, hydrographer for the water department of the city of Philadelphia. The results by months from 1890 to 1898, inclusive, are given in the Twentieth Annual Report, Part IV, beginning on page 98. The following table gives the figures of daily flow for 1899:

Daily discharge in second-feet of Tohickon Creek at Point Pleasant, Pennsylvania, for 1899.

[Drainage area, 102.2 square miles.]

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	144	158	793	178	35	15	14	4	18	46	52	34
2	136	125	601	131	31	9	11	399	13	40	181	34
3	154	118	601	97	31	9	19	267	9	27	121	44
4	204	151	708	79	31	10	12	113	93	25	221	43
5	1,172	184	2,819	68	31	9	10	52	42	23	366	44
6	1,360	210	1,109	61	27	8	10	28	28	18	121	39
7	1,400	189	520	73	23	7	8	22	19	20	73	36
8	503	142	277	1,328	23	7	8	17	16	23	58	36
9	503	180	217	389	23	5	7	15	287	20	53	31
10	413	183	203	160	20	8	6	254	210	17	40	33
14	124	110	418	108	28	6	7	417	203	17	35	34
15	158	90	1,225	92	35	6	5	182	499	16	42	44
16	169	119	1,702	87	27	7	7	66	163	13	51	36
17	569	102	416	79	31	5	11	38	58	11	53	101
18	488	782	502	70	31	3	9	28	46	10	47	60
19	258	767	2,492	84	27	153	20	5	5	19	36	9	46	49
20	177	695	938	68	20		17	5	7	14	18	9	47	44
21	116	914	308	61	17		20	4	7	12	18	9	45	39
22	84	1,414	1,051	58	17		7	3	8	11	23	9	39	39
23	79	1,582	1,006	53	20		2	2	8	8	708	9	34	35
24	526	1,000	449	49	17		2		3	8	545	9	33	101
25	2,032	541	220	49	17		2	3	5	6	404	9	33	65
26	382	616	624	45	15		7	3	4	7	239	14	49	53
27	230	3,222	633	41	12		12	4	4	7	61	16	57	89
28	145	1,058	779	39	9		5	4	4	33	42	18	44	913
29	166	.....	1,307	39	12		17	6	7	34	2	1,522	18	35	258
30	169	.....	520	39	14		27	7	4	27	604	11	30	97
31	184	.....	239	.....	15		.....	4	27	.....	158	11	31	79
											78	10	36	65
											51	12	39	53
											.....	17	.....	49
Mean	419	546	797	144	22	7	7	90			27	17	94	113

NESHAMINY CREEK AT FORKS, PENNSYLVANIA.

The drainage basin of this creek is immediately south[illegible] Tohickon Creek. The waters of Big Neshaminy flow in[illegible] of that of easterly course, and after joining the Little Neshaminy [illegible] a general southerly and empty into Delaware River about 12 miles [illegible] city of Philadelphia. Measurements of the discharge of the [illegible] have been made at the forks, where the drainage area is 139 [illegible] miles. The monthly discharges from 1890 to 1898 are given [illegible]

Twentieth Annual Report, Part IV, beginning on page 104. The following table gives the daily discharge for 1899:

Daily discharge in second-feet of Neshaminy Creek at Forks, Pennsylvania, for 1899.

[Drainage area, 139.3 square miles.]

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	527	213	611	349	67	31	15	27	15	38	144	54
2	458	213	569	280	73	31	13	248	15	31	154	51
3	97	213	540	243	67	27	9	2,162	28	31	162	48
4	71	213	686	221	61	19	10	104	41	27	1,257	57
5	405	173	3,687	201	53	17	14	43	32	22	252	54
6	2,105	119	913	176	50	17	13	23	19	38	145	48
7	1,298	97	573	255	47	13	10	15	15	59	107	41
8	306	97	377	1,047	45	13	13	15	15	53	85	41
9	277	105	388	362	46	15	14	14	13	36	81	36
10	213	97	343	245	38	19	14	488	43	27	81	36
11	213	80	510	204	64	19	13	2,577	38	22	81	36
12	213	72	959	186	89	17	10	151	80	19	85	36
13	213	72	1,318	176	73	17	10	71	68	19	85	65
14	228	72	407	166	53	15	10	48	23	22	77	80
15	206	72	1,172	159	48	15	8	36	15	19	72	60
16	189	89	813	193	48	15	8	27	15	19	68	45
17	457	319	242	301	43	15	9	22	15	22	68	36
18	252	553	722	177	54	15	9	19	13	123	68	31
19	145	574	2,490	149	68	15	8	19	41	113	56	36
20	115	974	742	139	57	15	6	17	430	57	51	57
21	105	1,373	382	129	36	15	6	14	166	41	48	72
22	105	1,373	1,765	115	36	15	6	19	138	32	41	57
23	100	1,402	976	105	44	15	6	19	65	27	77	41
24	1,117	849	406	105	51	13	6	19	41	27	147	792
25	1,927	446	414	105	47	11	6	19	41	22	90	401
26	333	809	490	105	36	13	11	13	578	22	74	125
27	242	3,950	417	101	31	13	23	11	204	22	72	89
28	213	815	1,308	92	31	13	27	13	89	17	63	72
29	213	.....	2,417	88	27	14	22	13	63	24	63	72
30	213	.....	588	73	22	15	325	14	48	17	63	63
31	213	.....	443	.....	27	.....	68	15	.....	24	.....	48
Mean	411	551	895	208	49	16	23	174	80	34	130	89

PERKIOMEN CREEK AT FREDERICK, PENNSYLVANIA.

The drainage area of this stream is immediately west of that of Tohickon Creek. It flows in a general southerly course, emptying into Schuylkill River about 18 miles above Philadelphia. The point of measurement is at Frederick, about 12 miles above the mouth and above two large tributaries, known as West Swamp Creek and Northeast Branch. The monthly discharges from 1890 to 1898, inclusive, are printed in the Twentieth Annual Report, Part IV, beginning on page 90.

The following tables give the daily flow from the time the gage was established to 1899:

Daily discharge in second-feet of Perkiomen Creek at Frederick, Pennsylvania.

[Drainage area, 152 square miles.]

1884.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	.....	.....	.....	.....	.....	.....	.....	100	44	155	93
2	.....	.....	.....	.....	.....	.....	.....	.....	79	58	59	64
3	.....	.....	.....	.....	.....	.....	.....	.....	71	58	57	64
4	.....	.....	.....	.....	.....	.....	.....	.....	63	61	71	79
5	.....	.....	.....	.....	.....	.....	.....	.....	60	58	342	78
6	.....	.....	.....	.....	.....	.....	.....	.....	53	46	140	828
7	.....	.....	.....	.....	.....	.....	.....	.....	53	48	91	3,425
8	.....	.....	.....	.....	.....	.....	.....	.....	50	41	70	380
9	.....	.....	.....	.....	.....	.....	.....	.....	46	41	50	230
10	.....	.....	.....	.....	.....	.....	.....	.....	44	41	48	179
11	.....	.....	.....	.....	.....	.....	.....	.....	38	37	47	187
12	.....	.....	.....	.....	.....	.....	.....	.....	39	40	62	981
13	.....	.....	.....	.....	.....	.....	.....	.....	38	36	69	600
14	.....	.....	.....	.....	.....	.....	.....	.....	33	33	75	256
15	.....	.....	.....	.....	.....	.....	.....	.....	35	25	75	2,409
16	.....	.....	.....	.....	.....	.....	.....	.....	37	25	73	516
17	.....	.....	.....	.....	.....	.....	.....	.....	37	25	52	292
18	.....	.....	.....	.....	.....	.....	.....	.....	37	20	48	236
19	.....	.....	.....	.....	.....	.....	.....	.....	38	16	48	186
20	.....	.....	.....	.....	.....	.....	.....	60	37	16	57	139
21	.....	.....	.....	.....	.....	.....	.....	58	37	21	76	106
22	.....	.....	.....	.....	.....	.....	.....	56	47	23	96	465
23	.....	.....	.....	.....	.....	.....	.....	56	47	48	93	449
24	.....	.....	.....	.....	.....	.....	.....	45	41	51	768	320
25	.....	.....	.....	.....	.....	.....	.....	47	37	43	223	247
26	.....	.....	.....	.....	.....	.....	.....	50	32	40	142	182
27	.....	.....	.....	.....	.....	.....	.....	54	23	41	121	171
28	.....	.....	.....	.....	.....	.....	.....	58	23	45	121	199
29	.....	.....	.....	.....	.....	.....	.....	89	29	87	262	241
30	.....	.....	.....	.....	.....	.....	.....	110	40	168	142	367
31	.....	.....	.....	.....	.....	.....	.....	130	.....	238	.....	1,239
Mean	.....	.....	.....	.....	.....	.....	.....	68	48	51	124	491

1885.

1	1,639	113	123	1,582	124	85	35	28	28	23	86	175
2	373	109	204	710	126	79	25	19	36	23	706	194
3	229	109	242	495	129	58	25	1,582	24	21	306	200
4	174	111	222	3,192	115	47	17	1,673	8	26	155	184
5	173	112	521	627	102	44	9	174	9	34	113	166
6	2,600	104	703	454	93	44	24	89	16	35	89	153
7	981	100	568	319	244	28	17	65	25	41	78	124
8	435	100	238	315	805	41	29	277	23	31	613	115
9	359	98	197	273	358	65	26	135	30	31	862	250
10	291	2,107	189	255	227	47	25	73	31	26	267	970
11	232	210	164	237	192	46	32	60	27	8	162	340
12	251	252	151	238	161	35	31	51	24	15	132	181
13	615	217	151	209	133	36	30	43	20	22	113	1,250
14	313	184	211	189	128	31	22	76	24	70	101	2,546
15	290	193	223	157	132	33	33	86	28	67	83	583
16	587	1,795	418	143	120	41	35	61	32	45	81	308
17	1,372	832	322	143	95	34	27	50	27	42	86	239
18	283	857	204	133	87	28	23	37	19	26	73	217
19	271	274	176	112	90	28	12	34	25	24	60	204
20	228	234	136	117	77	28	21	41	15	22	65	159
21	201	190	136	115	69	23	24	34	20	118	57	140
22	181	149	93	98	80	32	23	32	16	243	46	143
23	163	147	67	92	92	22	15	29	14	95	349	133
24	144	130	81	94	95	28	14	39	21	54	685	139
25	141	115	185	100	87	29	14	41	19	37	440	113
26	153	121	652	150	94	25	10	42	19	38	382	79
27	151	111	911	201	90	21	15	40	10	46	348	67
28	155	101	992	171	74	16	17	46	19	39	261	85
29	145	.....	538	139	62	18	26	35	17	39	206	100
30	120	.....	250	124	58	30	29	26	24	228	192	87
31	113	.....	985	.....	60	.....	17	28	.....	175	.....	292
Mean	431	327	331	373	142	37	23	16	22	56	240	321

Daily discharge in second-feet of Perkiomen Creek at Frederick, Pennsylvania—Continued.

1886.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	452	280	237	1,548	96	101	83	95	38	30	52	141
2	218	235	214	482	79	88	73	86	41	29	67	114
3	167	236	193	335	89	111	67	74	35	22	33	73
4	950	304	174	308	87	137	71	57	28	27	30	62
5	3,044	214	177	449	84	104	59	50	22	22	51	55
6	516	172	163	4,021	83	76	52	47	28	17	36	44
7	300	155	143	1,626	90	79	47	57	29	23	53	65
8	222	159	163	640	3,094	78	50	61	34	20	55	59
9	255	162	143	445	893	72	42	57	32	23	53	71
10	237	163	158	365	323	181	329	62	26	16	49	63
11	245	4,388	134	282	242	255	190	56	34	29	41	59
12	199	3,638	138	267	209	122	101	50	30	24	36	50
13	152	4,395	150	358	466	73	93	42	29	23	96	116
14	153	1,120	139	327	816	1,967	68	35	33	19	131	374
15	143	809	151	241	349	780	215	34	29	21	77	268
16	148	711	160	203	584	311	280	38	28	19	68	173
17	156	349	152	191	311	231	368	47	36	17	46	171
18	171	304	141	174	217	217	171	44	44	25	373	212
19	164	310	173	176	246	143	401	46	40	25	330	820
20	177	282	184	160	253	111	161	37	31	25	143	445
21	168	135	1,163	146	297	96	120	33	33	30	99	252
22	234	213	651	131	196	97	133	26	31	28	54	172
23	213	202	329	118	278	839	120	25	29	27	382	138
24	152	182	219	125	204	447	84	33	28	23	385	182
25	146	1,555	196	127	198	276	64	34	26	28	1,236	762
26	143	1,661	180	138	173	216	90	30	31	23	1,597	249
27	156	363	184	131	138	153	225	32	30	58	280	203
28	707	225	550	136	181	120	378	27	27	114	168	179
29	1,191	.....	535	121	148	100	171	25	25	87	145	123
30	877	.....	1,302	106	109	88	111	23	35	89	134	102
31	359	.....	1,827	.....	104	.....	84	29	.....	58	.....	91
Mean.	400	819	336	462	343	256	145	45	31	33	210	190

1887.

1	425	274	326	203	118	93	36	1,416	52	101	46	53
2	388	193	264	212	120	136	34	537	50	79	49	40
3	246	184	269	250	110	140	31	259	50	65	42	42
4	153	269	217	242	109	103	29	158	42	82	41	42
5	90	244	198	197	103	57	1,129	133	42	65	40	67
6	85	196	194	157	92	55	1,474	117	53	84	22	95
7	110	674	395	144	173	101	290	139	71	54	23	77
8	99	1,160	989	133	279	115	156	95	53	47	26	63
9	90	874	788	138	286	89	130	83	31	39	39	58
10	76	515	1,156	121	180	71	437	66	29	38	47	124
11	112	899	649	128	139	61	168	66	25	47	59	1,250
12	102	592	324	117	119	47	107	82	559	46	68	372
13	92	244	285	104	96	41	74	84	278	41	51	195
14	908	206	277	104	79	47	62	66	151	46	42	163
15	1,107	648	208	102	63	41	54	54	111	41	54	384
16	401	658	190	112	71	37	49	68	56	33	52	523
17	288	377	163	98	74	36	373	67	63	30	48	207
18	356	2,369	162	143	64	47	129	114	51	40	47	128
19	280	2,061	170	279	55	52	79	128	49	48	47	180
20	205	530	149	322	54	50	68	77	74	45	106	187
21	152	412	160	166	52	55	60	58	53	77	126	287
22	261	501	530	133	45	49	70	58	52	136	91	325
23	641	428	469	146	41	887	627	239	66	72	70	300
24	4,099	706	365	201	54	295	561	919	50	54	57	238
25	869	417	763	155	71	123	214	286	39	66	60	177
26	560	291	546	252	67	73	140	140	48	65	58	174
27	324	809	314	209	54	56	313	96	59	59	47	155
28	255	504	883	159	47	60	126	69	53	48	52	756
29	1,967	.....	477	227	48	47	104	68	62	50	66	995
30	1,069	.....	226	176	57	38	131	70	106	48	56	517
31	445	.....	227	.....	60	.....	1,198	58	.....	44	.....	432
Mean.	523	615	397	171	96	103	273	189	83	58	54	277

Daily discharge in second-feet of Perkiomen Creek at Frederick, Pennsylvania—Continued.

1888.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4,305	109	278	424	120	136	50	31	55	110	108	179
2	3,318	108	279	369	124	82	43	77	49	117	144	149
3	765	121	311	317	112	69	38	24	38	96	136	138
4	429	95	338	248	92	62	31	26	44	72	120	143
5	363	257	252	432	75	57	29	26	40	70	120	135
6	279	604	207	2,750	88	55	29	63	38	69	124	144
7	318	461	183	556	104	52	30	85	34	348	119	134
8	773	272	168	347	101	51	27	52	33	161	101	126
9	528	321	153	279	92	48	25	64	175	109	160	143
10	325	253	193	1,545	92	43	84	60	157	88	541	262
11	241	241	692	1,937	117	46	67	38	99	71	491	178
12	209	156	1,150	525	173	50	44	111	211	79	227	146
13	186	146	352	424	186	83	36	180	229	87	176	120
14	288	150	396	341	155	40	30	99	142	87	159	93
15	234	154	380	314	148	39	22	58	101	87	1,307	115
16	255	168	521	517	138	37	19	42	99	81	715	80
17	209	172	862	456	109	42	22	38	2,691	81	381	4,786
18	201	125	912	284	87	47	19	40	5,305	90	249	2,775
19	174	159	444	247	123	43	18	32	576	88	1,344	601
20	151	1,167	779	251	130	35	27	28	342	107	825	338
21	128	3,285	3,539	241	96	36	27	912	2,804	104	370	265
22	121	1,171	1,533	198	79	32	24	3,336	424	81	275	230
23	112	843	429	174	75	29	19	311	253	85	220	201
24	104	708	347	159	82	32	13	137	194	114	198	174
25	113	2,459	408	151	95	33	15	92	170	141	190	179
26	99	2,322	934	134	118	28	17	60	207	100	225	191
27	121	1,290	1,656	124	111	24	23	52	167	525	368	364
28	144	368	1,009	127	129	32	45	52	125	333	327	469
29	121	312	1,412	120	313	147	55	40	106	592	224	235
30	108	.....	691	118	171	72	46	43	93	270	201	161
31	114	.....	544	.....	124	.....	53	48	.....	184	.....	186
Mean.	475	643	676	470	122	53	33	202	500	165	338	433

1889.

1	190	208	75	351	241	2,187	245	1,648	60	153	268	352
2	177	190	125	850	199	729	775	657	80	163	226	295
3	168	185	605	338	171	320	1,401	461	78	187	1,004	314
4	159	169	4,235	231	155	252	1,063	393	70	113	679	278
5	215	174	1,480	190	142	209	715	412	67	103	353	296
6	787	190	628	168	125	182	334	334	71	104	266	246
7	508	166	364	142	115	134	232	229	80	123	224	246
8	310	143	282	123	105	116	182	181	71	115	246	305
9	834	142	218	115	94	116	150	164	72	103	5,389	522
10	918	128	185	106	93	172	133	181	78	90	1,147	327
11	360	123	175	100	158	170	398	173	83	87	560	257
12	290	101	165	109	119	374	264	136	132	90	453	251
13	220	104	160	139	104	239	361	131	222	193	1,792	221
14	208	122	165	143	127	153	440	1,284	252	285	1,421	300
15	183	104	158	113	137	387	4,016	1,613	208	389	508	386
16	178	197	150	105	110	754	550	252	219	231	373	322
17	1,553	791	150	93	86	446	276	227	3,130	150	300	616
18	634	1,182	166	91	76	752	199	181	3,020	181	330	397
19	374	452	173	91	60	244	188	158	606	119	2,266	353
20	209	219	167	82	343	162	458	143	410	115	1,039	355
21	578	185	257	71	745	133	223	131	302	209	725	297
22	526	149	558	82	339	168	157	123	234	186	926	253
23	480	113	302	81	189	119	130	115	178	207	471	284
24	281	101	206	71	134	93	118	115	173	178	347	198
25	340	113	184	63	115	90	104	107	430	140	316	198
26	359	114	150	593	148	881	96	100	416	134	620	349
27	724	102	137	1,894	630	627	132	98	261	3,356	670	295
28	871	82	173	1,210	723	249	172	90	185	1,202	2,808	202
29	393	.....	175	536	268	175	163	84	153	451	715	181
30	248	.....	143	262	177	225	598	74	139	294	462	171
31	235	.....	126	.....	232	.....	5,567	67	.....	256	.....	161
Mean.	436	216	395	285	208	361	640	326	383	311	913	298

Daily discharge in second-feet of Perkiomen Creek at Frederick, Pennsylvania—Continued.

1890.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	151	192	687	415	133	104	45	54	83	55	140	64
2	189	156	372	377	135	136	447	62	71	57	129	84
3	171	213	289	290	117	176	535	49	60	948	125	78
4	198	249	237	1,246	153	167	304	49	64	249	118	125
5	188	298	225	1,124	1,084	117	149	54	69	137	115	130
6	238	192	202	387	536	127	95	74	63	182	112	110
7	186	148	190	360	456	179	71	77	62	451	106	116
8	172	3,699	245	381	283	120	60	65	59	329	89	133
9	152	7,051	165	1,149	220	98	58	148	59	192	83	124
10	141	445	215	847	181	89	52	88	64	135	91	94
11	142	1,521	736	407	165	92	48	64	54	112	138	93
12	132	303	806	316	243	243	43	70	57	108	196	86
13	143	257	444	277	145	664	38	62	796	102	140	85
14	132	1,080	1,156	254	510	189	37	85	331	135	117	80
15	1,368	874	1,397	225	1,172	125	52	95	842	143	104	70
16	1,215	325	626	199	436	103	72	64	876	122	92	71
17	440	287	412	191	268	97	88	45	453	321	200	314
18	202	257	351	177	202	95	125	92	213	264	308	1,006
19	236	228	306	171	175	79	89	119	161	186	174	298
20	396	827	352	167	288	60	61	803	120	191	136	183
21	341	827	1,507	157	375	67	46	260	95	156	112	132
22	201	248	4,048	146	187	122	54	267	91	129	102	145
23	144	212	2,062	139	147	105	53	162	87	623	92	136
24	154	363	699	143	133	107	48	106	75	1,754	91	121
25	154	357	510	198	122	93	109	91	71	632	94	104
26	145	332	355	215	1,514	64	1,018	91	60	349	80	135
27	190	259	425	200	2,510	55	212	699	98	246	79	108
28	129	527	1,583	203	497	49	115	256	86	191	73	97
29	138	.....	801	160	278	48	113	189	71	173	76	100
30	368	.....	459	142	206	50	103	124	68	238	71	108
31	254	.....	395	.....	179	.....	71	101	.....	171	.....	93
Mean	271	774	735	355	421	127	142	146	179	309	119	149

1891.

1	75	1,917	238	433	105	48	28	163	236	54	51	196
2	1,931	892	206	364	103	54	28	113	210	48	42	53
3	941	760	288	870	214	50	34	84	156	50	42	51
4	298	607	201	421	243	46	36	172	129	38	37	1,225
5	219	322	211	815	139	45	33	187	2,367	38	44	1,184
6	176	260	199	242	115	40	36	146	890	38	49	256
7	149	451	217	211	94	66	33	144	396	42	37	734
8	128	762	236	179	90	117	43	74	235	73	27	456
9	101	652	711	174	92	78	77	53	178	88	30	225
10	94	977	1,200	165	78	52	53	48	145	59	38	169
11	1,705	424	509	379	83	41	37	46	120	42	89	113
12	3,431	308	551	786	76	37	29	45	108	49	124	75
13	400	272	1,352	320	65	36	23	58	99	51	71	75
14	246	239	630	233	67	32	31	58	91	45	59	75
15	206	181	514	205	68	34	45	220	85	42	41	75
16	168	1,312	462	181	96	38	43	151	80	49	52	75
17	206	1,323	233	180	97	38	38	86	77	49	123	75
18	483	781	224	177	77	55	162	228	71	40	193	75
19	304	410	209	160	78	69	413	406	66	31	110	75
20	239	363	883	147	72	65	142	155	51	275	71	60
21	209	832	4,803	135	70	58	73	109	52	173	79	59
22	3,945	1,012	1,275	140	67	84	54	176	66	134	50	80
23	970	432	1,007	158	59	73	47	116	49	220	114	895
24	390	339	640	155	61	54	81	1,169	45	118	303	1,197
25	539	342	426	129	59	36	91	1,915	53	72	138	928
26	446	307	325	107	60	30	47	374	49	67	100	791
27	379	331	298	111	72	20	45	355	47	79	94	779
28	341	215	299	113	65	27	46	573	47	79	83	408
29	782	.....	278	104	51	26	812	274	40	70	66	307
30	1,315	.....	245	103	55	28	425	362	52	48	49	725
31	862	.....	.....	.....	.....	.....	352	368	.....	48	.....	261
Mean.	699	613	624	247	89	49	111	272	209	74	80	379

Daily discharge in second-feet of Perkiomen Creek at Frederick, Pennsylvania—Continued.

1892.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	201	184	2,073	229	83	127	275	239	75	26	31	174
2	1,482	202	610	213	100	105	184	146	67	24	29	130
3	861	217	246	237	167	90	375	211	56	22	26	117
4	303	178	338	238	153	479	557	126	36	26	26	105
5	235	201	319	203	122	150	192	71	32	28	34	100
6	196	146	311	183	106	144	111	52	33	24	32	89
7	204	155	398	164	114	124	78	45	34	22	26	71
8	214	191	1,673	153	95	96	58	41	32	27	27	427
9	198	216	1,341	138	85	93	51	37	29	28	32	360
10	180	185	625	125	84	429	46	36	28	28	295	186
11	158	173	437	122	71	182	45	134	31	30	319	130
12	182	126	458	120	77	110	42	359	23	33	133	116
13	3,674	121	262	112	74	84	40	135	20	26	76	120
14	3,709	137	190	127	94	69	38	62	71	26	54	357
15	1,066	147	207	265	263	53	39	51	90	29	652	550
16	572	154	178	212	214	50	37	51	54	23	2,836	297
17	412	113	167	146	102	297	27	39	40	24	472	231
18	404	96	145	133	111	149	32	34	34	29	769	180
19	1,879	97	153	128	117	71	31	35	27	31	602	152
20	699	131	150	111	397	71	26	28	23	30	268	142
21	412	159	165	129	365	77	36	25	27	31	192	124
22	316	154	153	204	420	57	36	24	33	30	156	112
23	300	158	173	247	337	41	23	24	42	29	168	117
24	275	151	462	169	241	49	18	26	56	40	88	100
25	288	144	906	131	160	65	18	51	59	43	76	48
26	251	189	570	125	872	59	20	571	61	33	84	58
27	207	209	1,688	106	1,491	64	23	155	58	30	68	58
28	178	155	1,074	87	400	171	22	87	46	29	226	52
29	176	158	1,479	91	219	102	88	68	40	17	506	45
30	185	.....	815	102	175	80	176	62	57	4	229	35
31	168	.....	259	.....	155	.....	379	72	.....	32	.....	33
Mean.	634	166	565	158	241	125	101	100	44	27	288	155

1893.

1	258	257	213	157	249	78	36	21	50	26	43	108
2	1,169	597	264	144	343	78	37	30	46	30	41	143
3	268	702	252	138	998	158	37	25	46	27	42	301
4	166	535	202	136	5,139	96	36	22	44	24	867	806
5	128	335	184	118	857	86	36	19	43	25	1,470	265
6	128	244	187	101	979	156	34	16	41	25	372	199
7	94	1,021	168	113	479	197	35	14	36	30	202	204
8	93	714	217	208	349	107	35	15	38	29	158	158
9	122	383	2,224	177	283	68	63	18	41	26	386	137
10	138	3,247	3,546	190	185	59	62	22	32	27	168	168
11	128	1,534	1,221	392	201	51	46	24	32	28	102	243
12	165	512	3,401	345	185	54	40	24	36	29	84	171
13	170	602	1,493	172	177	58	39	22	28	32	87	126
14	145	854	1,089	436	177	49	39	22	26	1,939	91	101
15	132	913	937	1,587	183	44	33	19	40	105	160	109
16	138	1,190	385	506	260	38	97	14	978	53	177	989
17	169	566	320	299	548	37	118	13	315	50	112	1,091
18	190	300	325	235	249	37	60	13	140	38	88	346
19	174	318	297	196	175	43	42	16	93	30	71	226
20	165	251	275	486	138	40	33	1,129	67	34	76	137
21	172	224	358	1,061	122	38	24	289	52	34	84	130
22	173	226	369	407	115	63	22	92	43	34	341	121
23	171	198	315	268	116	86	26	55	39	38	231	135
24	160	173	340	212	115	71	31	1,166	34	74	133	127
25	138	163	335	201	106	43	28	289	33	78	104	141
26	118	153	300	195	97	77	23	110	36	45	78	177
27	102	147	240	320	91	93	21	59	38	43	83	113
28	102	166	206	355	88	67	24	44	29	263	1,118	98
29	116	.....	178	211	97	54	26	187	21	161	347	129
30	258	.....	172	186	96	39	23	150	25	93	199	149
31	304	.....	169	.....	84	.....	14	69	.....	65	.....	117
Mean.	192	591	649	317	428	72	39	129	83	113	251	241

Daily discharge in second-feet of Perkiomen Creek at Frederick, Pennsylvania— Continued.

1894.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	109	138	166	120	96	509	131	23	17	36	412	78
2	101	120	197	120	76	348	82	88	27	36	193	339
3	101	98	464	109	57	277	70	154	25	46	908	364
4	97	68	776	149	61	235	45	109	14	55	428	176
5	120	74	822	333	64	212	40	57	15	63	805	126
6	153	88	1,045	175	103	207	571	42	15	51	786	114
7	145	80	1,024	135	128	206	241	35	17	38	369	103
8	125	88	524	128	91	191	99	29	249	45	350	125
9	111	704	390	123	67	167	68	31	483	36	429	387
10	92	1,002	311	117	52	143	55	33	137	2,335	303	223
11	74	638	280	168	48	131	43	31	292	530	261	638
12	62	343	249	329	48	118	38	31	101	182	188	4,132
13	59	198	214	1,119	41	118	38	35	59	209	165	1,841
14	58	182	188	898	36	121	36	52	43	290	161	446
15	67	172	169	446	38	104	34	57	43	160	146	326
16	80	160	176	239	38	91	224	47	40	118	123	266
17	89	152	170	229	37	84	44	43	63	98	133	226
18	92	975	136	190	40	80	29	35	1,123	80	178	187
19	80	1,175	136	170	52	81	23	41	2,490	59	130	161
20	69	1,284	142	163	1,634	77	23	57	984	51	111	151
21	56	632	132	183	8,769	72	31	50	243	48	115	145
22	74	442	161	269	3,787	64	46	48	144	49	126	138
23	88	308	479	262	539	60	38	40	99	55	119	117
24	80	163	291	168	3,541	132	48	38	90	61	120	114
25	97	187	156	138	1,398	298	75	36	71	717	101	111
26	88	165	195	121	708	113	45	30	47	309	95	137
27	62	154	161	113	566	94	38	24	54	179	100	123
28	55	157	126	105	2,442	85	38	22	51	130	78	130
29	76	.....	158	93	1,822	68	37	32	46	108	70	145
30	147	.....	168	94	541	132	35	26	43	98	72	119
31	168	.....	138	.....	519	.....	31	14	.....	513	.....	102
Mean.	93	355	314	234	885	154	77	45	23	219	252	374

1895.

1	102	138	1,192	168	236	51	393	31	30	16	84	51
2	80	128	1,235	327	163	47	151	34	30	16	82	43
3	80	122	454	463	133	43	70	34	33	18	64	155
4	86	136	418	252	128	62	56	35	31	20	47	95
5	84	143	416	181	114	79	667	30	31	25	54	67
6	115	86	240	158	101	138	489	31	29	5	54	55
7	607	98	249	143	108	115	172	22	22	21	44	45
8	830	158	1,238	1,910	106	70	105	24	19	8	45	43
9	544	178	789	4,203	94	50	71	28	23	19	44	38
10	354	222	689	682	78	50	48	24	26	13	33	41
11	2,372	243	711	380	73	55	45	75	26	17	49	45
12	905	214	323	296	134	44	40	133	22	25	65	37
13	586	196	845	1,018	151	52	39	104	18	117	38	33
14	333	186	1,528	845	205	68	37	58	16	177	43	33
15	244	171	448	393	271	55	33	39	6	63	26	30
16	242	152	312	286	151	40	37	31	24	50	52	31
17	249	136	242	232	114	36	43	31	20	41	46	25
18	187	134	313	200	101	34	40	31	18	29	49	29
19	157	141	512	175	87	30	36	29	22	33	55	30
20	137	154	476	151	80	28	31	18	26	11	52	119
21	136	184	317	156	91	30	26	18	26	22	41	127
22	142	225	324	154	120	34	23	26	20	25	36	486
23	151	193	306	154	92	36	26	27	27	24	35	197
24	148	118	334	138	76	32	33	23	27	26	18	118
25	125	114	456	126	72	31	36	18	24	22	39	80
26	2,212	117	496	126	59	35	27	19	24	24	37	71
27	559	198	282	266	236	88	21	23	22	12	39	117
28	235	320	280	247	348	104	23	24	22	33	131	117
29	191	.....	222	177	139	87	21	26	4	21	85	71
30	178	.....	181	236	85	141	34	38	18	21	55	110
31	165	.....	161	.....	66	.....	30	41	.....	24	.....	1,191
Mean.	404	182	516	475	129	59	94	37	23	32	51	120

Daily discharge in second-feet of Perkiomen Creek at Frederick, Pennsylvania—Continued.

1896.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	327	56	586	351	63	65	51	123	21	179	42	236
2	150	91	338	322	55	53	39	84	20	60	43	160
3	124	106	188	256	57	42	44	73	21	45	54	126
4	91	111	124	189	71	39	41	64	22	38	57	125
5	58	85	119	161	71	36	68	45	38	45	2,439	116
6	47	6,789	95	156	50	34	36	40	756	66	829	97
7	42	2,181	99	166	45	28	39	40	212	60	295	109
8	31	381	92	148	49	30	60	35	81	41	344	120
9	37	347	72	117	42	41	280	28	52	41	377	406
10	40	335	78	120	34	91	457	83	42	39	217	223
11	35	291	80	133	37	95	133	66	30	33	191	150
12	34	196	59	120	38	44	69	35	30	585	282	118
13	34	177	63	108	37	31	47	34	28	2,711	231	102
14	37	569	67	99	23	36	41	32	23	476	178	100
15	38	360	55	86	39	78	40	25	30	259	137	98
16	31	415	60	80	39	82	41	25	39	164	119	85
17	20	121	82	81	25	118	38	26	37	122	113	87
18	22	123	96	98	25	177	33	31	358	98	100	95
19	30	112	1,854	109	32	75	25	34	95	82	89	81
20	31	112	3,150	89	34	49	23	32	81	71	82	60
21	34	90	875	125	65	39	1,532	32	56	63	77	73
22	34	54	618	127	92	40	863	31	52	63	75	70
23	36	52	521	83	65	36	1,143	25	39	52	84	55
24	193	93	259	81	38	37	169	26	31	125	88	58
25	379	116	316	149	35	66	115	31	30	138	87	58
26	156	75	655	114	35	94	79	26	33	82	72	55
27	105	70	700	84	38	125	70	26	34	68	65	52
28	86	69	301	78	165	71	177	31	26	60	175	55
29	60	638	2,520	66	300	124	297	24	36	57	895	58
30	43	.....	1,052	67	119	88	1,938	17	287	57	379	47
31	43	.....	465	.....	74	.....	250	20	.....	53	.....	36
Mean	78	493	504	132	61	65	264	41	88	195	280	107

1897.

1	51	46	131	88	82	105	45	86	35	22	70	136
2	78	55	128	85	2,580	88	46	180	113	18	3,089	113
3	85	55	162	76	1,330	80	33	61	159	13	103	95
4	124	49	246	67	381	124	30	54	75	17	169	161
5	318	55	211	139	268	180	34	213	67	17	100	1,942
6	547	965	545	200	199	150	34	117	37	10	70	513
7	83	4,083	315	149	148	105	29	58	33	15	47	396
8	76	846	200	115	124	118	35	55	29	22	34	207
9	61	346	172	1,643	112	890	43	45	34	18	96	166
10	51	204	180	988	124	473	38	53	32	8	120	146
11	52	171	198	311	131	106	30	201	13	15	84	138
12	47	123	221	218	138	127	203	120	8	23	106	360
13	38	110	212	185	4,747	106	248	66	29	22	88	355
14	49	115	168	153	1,566	97	38	49	29	29	41	1,909
15	45	110	199	323	1,003	84	56	48	35	28	44	2,561
16	39	161	189	316	425	75	44	149	36	17	60	239
17	46	184	129	265	365	75	41	167	29	16	87	325
18	117	413	139	216	300	85	213	68	26	27	97	249
19	150	351	322	166	173	85	292	50	23	30	70	185
20	96	153	730	129	153	64	130	47	19	14	51	145
21	1,291	347	392	116	217	61	104	41	23	16	51	151
22	504	664	242	110	221	63	588	39	25	23	67	166
23	157	1,242	201	99	137	63	231	33	22	20	60	141
24	115	457	564	94	202	51	128	30	35	28	60	99
25	136	244	405	80	442	46	77	112	46	88	62	73
26	130	193	208	84	201	50	60	123	38	89	93	71
27	93	158	167	94	126	37	475	52	29	62	1,117	89
28	81	136	146	76	103	35	1,901	37	31	50	317	94
29	69	.....	128	70	93	38	729	26	27	49	219	82
30	51	.....	120	61	83	35	236	27	22	47	183	88
31	48	.....	98	.....	99	.....	127	28	.....	39	.....	130
Mean	156	429	241	223	525	128	205	78	40	29	238	364

Daily discharge in second-feet of Perkiomen Creek at Frederick, Pennsylvania—Continued.

1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	163	145	153	292	201	113	29	32	40	28	129	383
2	37	137	138	213	160	103	30	38	28	20	90	242
3	69	147	168	178	147	96	34	46	23	29	76	233
4	62	129	183	157	141	93	29	49	19	31	70	1,916
5	45	114	153	151	148	75	29	139	27	23	78	3,406
6	59	114	127	171	199	60	30	104	25	21	63	569
7	101	116	115	184	497	63	28	50	34	18	45	352
8	121	125	115	155	3,493	59	29	43	51	23	94	218
9	102	140	107	129	1,380	46	57	116	45	26	52	100
10	94	182	107	113	495	37	64	332	29	31	1,422	102
11	106	348	102	121	398	39	39	393	25	27	1,100	92
12	205	541	99	127	495	46	35	145	22	27	272	97
13	302	414	99	108	580	54	37	82	19	30	173	100
14	253	307	98	106	415	50	37	56	24	30	167	91
15	542	248	89	323	1,403	41	37	44	25	56	150	78
16	661	272	76	259	1,013	50	37	43	17	56	103	70
17	296	159	85	170	713	56	18	45	15	40	202	72
18	166	166	88	122	377	44	28	46	13	45	447	78
19	147	258	88	113	392	49	39	258	12	39	8,808	111
20	585	5,552	74	126	289	64	190	71	14	71	602	890
21	704	1,650	133	125	345	66	115	60	17	57	312	384
22	375	739	426	102	232	56	73	51	27	162	233	552
23	2,758	474	445	95	211	53	51	50	42	116	763	1,364
24	570	332	341	658	255	51	41	47	54	61	408	452
25	323	265	340	428	422	39	37	47	61	60	317	308
26	454	218	220	433	353	36	39	39	52	235	267	215
27	393	182	173	285	268	37	40	35	43	475	207	189
28	261	166	282	481	219	41	65	30	43	163	213	150
29	205	.....	414	641	168	45	74	24	45	93	330	126
30	166	.....	894	312	153	41	48	24	38	111	395	139
31	166	.....	456	.....	131	.....	37	38	.....	198	.....	230
Mean.	338	486	206	229	505	56	44	83	30	77	416	428

1899.

1	313	131	651	346	78	76	84	72	53	147	294	68
2	239	130	635	262	82	66	52	346	440	101	286	114
3	239	120	589	248	98	49	45	722	922	99	181	84
4	222	182	753	252	101	38	41	177	318	101	724	69
5	1,014	198	3,525	230	84	36	41	90	174	93	309	71
6	1,315	143	975	185	83	36	41	77	106	98	184	56
7	1,476	148	588	245	74	38	36	66	57	119	138	55
8	394	152	391	1,366	70	39	41	52	43	105	109	64
9	311	174	365	428	87	41	816	48	290	95	107	56
10	239	183	345	296	73	48	163	157	227	80	104	44
11	195	158	475	251	101	49	71	1,021	213	72	88	43
12	165	170	1,519	219	213	43	43	224	369	67	110	146
13	150	222	1,552	187	129	38	42	90	189	57	112	250
14	245	236	510	178	125	39	43	66	97	53	62	127
15	410	225	848	170	123	44	38	54	71	57	62	84
16	475	255	879	260	83	34	35	46	54	48	92	75
17	789	233	437	501	93	26	38	52	46	51	77	67
18	443	683	853	263	201	29	42	42	55	65	60	55
19	196	992	2,423	196	210	27	42	37	58	80	58	133
20	192	1,311	780	160	129	26	40	36	748	81	67	182
21	164	1,495	421	146	86	32	33	29	385	67	65	127
22	145	1,507	1,146	136	70	65	27	53	206	63	53	79
23	147	1,767	893	118	96	41	25	61	184	57	159	57
24	1,081	869	517	113	98	43	25	44	115	49	200	662
25	2,693	469	417	120	70	83	26	39	110	34	116	531
26	378	1,184	534	114	57	110	70	34	3,363	34	79	177
27	289	4,043	513	99	60	74	82	502	462	60	75	133
28	212	883	1,002	87	60	165	98	197	258	62	81	91
29	201	.....	1,377	81	71	501	89	84	174	51	66	59
30	153	.....	555	76	122	220	817	64	168	71	65	51
31	129	.....	466	.....	93	.....	158	63	.....	78	.....	47
Mean.	472	659	869	245	100	74	104	150	332	74	139	124

WISSAHICKON CREEK NEAR PHILADELPHIA, PENNSYLVANIA.

The drainage basin of this creek is immediately adjacent to Philadelphia, and between Little Neshaminy and Perkiomen creeks. Measurements of flow were begun in April, 1897, under the direction of Mr. John E. Codman, at a point about 100 yards above the junction of the creek with Schuylkill River. The results for 1897 and 1898 have been printed in the Twentieth Annual Report, Part IV, and the daily flow to June 1, 1899, is given in the following table:

Daily discharge in second-feet of Wissahickon Creek, near Philadelphia, Pennsylvania, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	Day.	Jan.	Feb.	Mar.	Apr.	May.	June.
1	141	119	285	191	89	45	18	147	227	273	129	96	.....
2	106	106	245	175	96	42	19	118	350	603	129	90	.....
3	106	110	233	175	108	42	20	116	466	340	123	73	.....
4	120	204	233	173	93	33	21	115	436	202	115	68	.....
5	412	204	1,059	159	80	21	22	106	779	521	106	75	.....
6	574	113	365	151	90	.....	23	106	630	328	106	96	.....
7	573	113	241	166	87	.....	24	259	359	232	106	96	.....
8	220	113	204	451	87	.....	25	925	250	202	106	75	.....
9	194	113	186	205	75	.....	26	184	245	216	106	64	.....
10	154	113	198	152	75	.....	27	142	1,285	198	106	64	.....
11	140	113	198	140	105	.....	28	133	423	434	101	54	.....
12	132	113	198	140	108	.....	29	136	.....	813	98	50	.....
13	118	113	540	140	90	.....	30	136	.....	260	95	59	.....
14	144	113	208	137	87	.....	31	136	.....	218	.....	54	.....
15	149	113	346	129	87	.....							
16	140	113	359	142	87	.....	Mean	207	271	326	146	81	.....
17	232	149	186	142	87	.....							

SCHUYLKILL RIVER NEAR PHILADELPHIA, PENNSYLVANIA.

This river receives the drainage of the portion of southeastern Pennsylvania lying between the Lehigh River on the north and the Susquehanna River on the south. It flows in a general southeasterly course, emptying into Delaware River, the city of Philadelphia being located at the junction of these streams. Records of the height of the river at Fairmount pool have been kept for many years, but not in such form as to be useful in computing daily discharges. In 1898, however, careful estimates were prepared by Mr. John E. Codman, the results being given in the Twentieth Annual Report, Part IV, page 97. The figures for 1899 are given in the following table:

These do not represent the total flow of the stream, but the amount wasted over the flashboards at Fairmount dam. To this must be added the pumpage from the river, amounting to 275,000,000 gallons per day, or 425 second-feet; also the leakage, amounting to 71,000,000 gallons per day, or 110 second-feet; also the quantity used for power at Fairmount, amounting to an average per day of 272,000,000 gallons, or 421 second-feet. There has been no method for obtaining the daily flow when the water does not waste over the flashboards. When the water is below the overflow line recourse is had to pumping, and the draft is on the storage of the pool. As soon as the water begins to rise after a rain the turbine wheels are started and, thus it often

occurs that no water flows to waste for from one to three months in succession.

Daily discharge in second-feet of Schuylkill River above Philadelphia, Pennsylvania, for 1899, being amount wasted over flashboards at Fairmount Dam.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	573	566	11,170	5,321	.....	440	385	514	.....	.....	60	.....
2	170	566	8,532	4,156	.....	204	.....	.....	.....	.....	605	.....
3	26	347	6,717	3,352	.....	341	.....	2,421	964	.....	477	.....
4	135	1,023	6,421	2,910	.....	179	.....	414	217	.....	1,961	.....
5	3,033	1,250	17,735	2,481	.....	.....	.....	.....	.....	.....	3,002	.....
6	6,017	791	13,186	2,210	.....	.....	.....	.....	.....	.....	1,415	.....
7	8,945	825	4,748	2,945	.....	.....	.....	.....	.....	.....	703	.....
8	2,521	342	7,120	7,735	.....	.....	.....	.....	.....	.....	831	.....
9	1,470	31	5,504	7,651	.....	.....	1,185	.....	.....	.....	733	.....
10	1,035	.....	4,805	5,068	46	.....	385	.....	179	.....	622	.....
11	816	.....	4,468	3,824	.....	.....	.....	4,775	.....	.....	.....	.....
12	511	.....	4,961	3,920	357	.....	.....	2,213	173	.....	.....	.....
13	248	.....	11,906	2,478	369	.....	.....	641	130	.....	83	857
14	436	.....	7,918	2,478	31	.....	.....	.....	.....	.....	83	1,012
15	693	.....	7,046	2,478	.....	.....	.....	.....	.....	.....	.....	159
16	950	50	8,948	2,478	.....	.....	.....	.....	.....	.....	.....	260
17	1,854	902	5,619	2,902	.....	.....	.....	.....	.....	.....	.....	.....
18	1,421	3,301	5,310	2,478	277	.....	.....	.....	.....	.....	.....	68
19	569	3,858	14,442	2,075	1,061	.....	.....	.....	.....	.....	.....	570
20	523	4,990	10,540	1,582	532	.....	.....	.....	550	.....	.....	610
21	526	5,908	10,748	1,012	240	.....	.....	.....	1,489	.....	.....	331
22	305	8,656	11,230	849	25	.....	.....	.....	1,042	.....	.....	331
23	305	9,746	11,548	337	.....	.....	.....	.....	49	.....	.....	.....
24	4,226	4,914	8,054	212	.....	.....	.....	.....	.....	.....	397	1,201
25	14,980	4,984	6,326	.....	.....	.....	.....	.....	.....	.....	397	3,854
26	7,062	1,605	6,134	.....	.....	624	.....	.....	10,923	.....	.....	2,902
27	1,752	17,177	5,874	.....	.....	241	.....	1,775	5,653	.....	.....	2,489
28	1,951	18,045	8,622	.....	.....	.....	.....	637	2,155	.....	.....	2,077
29	1,175	.....	13,757	.....	.....	1,238	.....	.....	1,154	.....	.....	1,277
30	967	.....	9,085	.....	.....	1,752	215	468	494	.....	.....	298
31	1,120	.....	6,718	.....	519	.....	1,920	396	.....	.....	.....	.....

Total monthly yield, in cubic feet, of Schuylkill River above Philadelphia, Pennsylvania, for 1899.

January	11,445,838,000	July	3,475,700,000
February	12,484,000,000	August	3,964,400,000
March	28,187,700,000	September	5,258,910,000
April	11,957,000,000	October	2,587,900,000
May	5,153,450,000	November	4,896,500,000
June	3,856,560,000	December	5,086,600,000

NORTH BRANCH OF SUSQUEHANNA RIVER AT WILKESBARRE, PENNSYLVANIA.

This stream rises in New York State and flows in a southwesterly direction until it crosses the Pennsylvania State line, when it flows to the southeast, turning again near Wilkesbarre to the southwest, and joins the West Branch of the Susquehanna on the western border of Northumberland County to form Susquehanna River. Measurements of flow are made at Wilkesbarre and Danville, Pennsylvania.

Observations of fluctuations of Susquehanna River are made by the Weather Bureau above Wilkesbarre, at Towanda, Pennsylvania, where the drainage area is estimated to be 8,000 square miles. The river gage, made of iron 1 foot wide and one-half inch thick, is on the east side of the road bridge over Susquehanna River, and is securely bolted to the masonry of the pier. The graduation is from 0 to 25 feet. The highest water was 29 feet in March, 1869, and the lowest,

—0.1, in October, 1895. The danger line is at 16 feet. The elevation of the zero is 633.7 feet.

The Wilkesbarre station was established by E. G. Paul on March 30, 1899, and is located at the Market street bridge. The gage is a sash chain and weight inclosed in a long, narrow box, covering 12 feet of the scale board. The scale board is divided into feet and tenths and painted the color of the ironwork. The length of the chain from zero to extreme end of weight is 40.83 feet. The initial point of sounding is at the end of the iron guard rail on the left bank. The channel is straight for a quarter of a mile above and below the station, the current sluggish but unobstructed. The right bank is low and liable to overflow; the left bank is above ordinary floods. The bed of the stream is of sand and gravel, somewhat shifting. The observer is O. Hemstreet, the bridge superintendent, Wilkesbarre, Pennsylvania. When this gage was established there was found to be a gage painted on the bridge pier, being a portion of one established by the Weather Bureau. The lower part of this gage, erected in January, 1898, originally consisted of heavy cast-brass plates graduated to feet and tenths. The gage plates were made in 4-foot sections and bolted to the stone bridge pier. The two lower sections of the brass plates had been torn away by ice, so that there was no graduation below the 8-foot mark, but readings were made by the figures painted on the stone pier. The zero of this old gage is at the base of the dressed-stone portion of the pier, and is reported to be 535 feet above sea level. During low stages of the river the water recedes from the pier, rendering it impracticable to read the gage. So far as could be ascertained, this has not been connected with the city datum. On account of the low water, which in 1897 had gone below the city datum, it was decided to put the zero of the new gage 4 feet below the zero of the old Weather Bureau gage, so as to obviate minus readings. In order, therefore, to compare with former records, it is necessary to add 4 feet to the old figures. The danger mark of this Weather Bureau gage is at 14 feet, or 18 feet of new gage, as at this elevation the west bank of the river is under water in places. River reports from this locality were furnished as early as 1888. During low water, measurements were made by wading at a better cross section, at Retreat, 10 miles below Wilkesbarre. The following measurements were made by E. G. Paul during 1899:

Measurements of North Fork of Susquehanna River at Wilkesbarre, Pennsylvania.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Second-ft.*	1899.	*Feet.*	*Second-ft.*
March 30	9.00	24,800	September 17	2.30	851
June 6	4.30	3,668	September 18	2.30	a1,096
July 26	2.80	a1,924	October 16	2.35	a1,114
July 27	2.80	a1,357			

a Made at Retreat, Pennsylvania, 10 miles below Wilkesbarre.

Daily gage height, in feet, of North Branch of Susquehanna River at Wilkesbarre, Pennsylvania, for 1899.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	8.40	6.40	4.50	3.60	2.70	3.10	2.50	2.50	3.40
2	.....	8.10	6.20	5.50	3.30	2.60	2.90	2.50	3.00	3.40
3	.....	7.70	6.30	5.30	3.30	2.70	2.60	2.50	8.30	3.40
4	.....	7.20	6.30	5.10	3.20	2.60	2.60	2.50	6.70	3.40
5	.....	6.90	6.40	4.60	3.00	3.20	2.50	2.50	7.30	3.50
6	.....	6.90	6.10	4.30	3.00	3.00	2.50	2.60	6.60	3.50
7	.....	7.40	5.70	3.60	2.80	2.80	2.50	2.60	6.90	3.50
8	.....	10.35	5.60	3.50	2.90	2.50	2.40	2.50	5.80	3.70
9	.....	14.10	5.40	3.50	2.80	2.50	2.40	2.50	5.00	3.60
10	.....	14.20	5.30	3.50	2.80	2.50	2.40	2.50	4.50	3.50
11	.....	12.80	5.10	3.30	2.80	2.50	2.40	2.50	4.20	3.50
12	.....	11.10	5.20	3.20	2.90	2.50	2.50	2.50	4.30	3.60
13	.....	11.30	5.10	3.20	2.90	2.70	2.50	2.40	4.90	7.70
14	.....	14.00	5.00	3.30	3.00	2.80	2.50	2.40	4.70	9.60
15	.....	14.30	5.00	3.00	3.20	2.80	2.40	2.40	4.60	9.60
16	.....	13.90	4.80	3.10	3.30	2.80	2.40	2.40	4.50	8.50
17	.....	13.40	4.80	3.20	3.10	2.90	2.30	2.30	5 20	7.70
18	.....	12.50	4.70	3.20	3.00	2.70	2.30	2.30	5.20	7.30
19	.....	11.30	4.90	3.00	3.00	2.40	2.30	2.30	5.30	6.50
20	.....	10.50	4.90	3.00	3.00	2.30	2.30	2.30	5.00	6.50
21	.....	9.90	5.40	3.10	3.10	2.30	2.30	2.30	4.70	8.30
22	.....	9.40	5.90	3.00	3.00	2.60	2.30	2.30	4.60	8.40
23	.....	9.00	5.80	3.00	3.00	2.50	2.30	2.30	4.30	7.40
24	.....	8.50	5.70	2.90	2.90	2.50	2.30	2.30	4.20	6.60
25	.....	8.00	5.50	2.90	2.80	2.40	2.20	2.30	4.00	8.40
26	.....	7.40	5.40	3.10	2.80	2.40	2.50	2.20	3.80	8.00
27	.....	7.60	5.10	3.10	2.80	2.40	2.40	2.30	3.80	7.40
28	.....	7.40	4.90	3.30	2.80	2.40	2.50	2.30	3.70	6.30
29	.....	7.10	4.80	3.80	2.80	4.60	2.50	2.50	3.60	9.10
30	9.00	6.60	4.80	4.00	2.60	4.10	2.60	2.50	3.50	7.90
31	8.70	.....	4.70	.....	2.60	3.40	.....	2.50	.....	.....

NORTH BRANCH OF SUSQUEHANNA RIVER AT DANVILLE, PENNSYLVANIA.

This station, 52 miles below Wilkesbarre and 11 miles above the mouth of the West Branch, was established on March 25, 1899, by E. G. Paul. It is located at the Mill street bridge, 600 feet south of the public square, Danville, Pennsylvania. The length of the wire gage from zero to the end of the weight is 42.85 feet. This gage is referred to a pine-board scale nailed to the hand rail of the bridge and divided into feet and tenths. The initial point of soundings is at the end of the wooden hand rail on right bank. The channel is straight for half a mile above and below the station. The left bank is high, but the right bank is subject to overflow. The bed of the stream is rocky, with some gravel, and is unchangeable. The following measurements were made by E. G. Paul during 1899:

March 25, gage height, 10.00 feet; discharge, 47,646 second-feet.
June 8, gage height, 3.00 feet; discharge, 3,927 second-feet.
July 27, gage height, 2.40 feet; discharge, 2,272 second-feet.
September 16, gage height, 2.00 feet; discharge, 1,427 second-feet.
October 17, gage height, 1.90 feet; discharge, 1,163 second-feet.

Daily gage height, in feet, of North Branch of Susquehanna River at Danville, Pennsylvania, for 1899.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	6.95	4.80	3.30	3.20	2.20	2.80	2.10	2.10	3.10
2	.....	6.80	4.65	3.40	3.00	2.20	2.60	2.10	2.60	3.00
3	.....	6.35	4.60	3.70	2.80	2.60	2.50	2.10	2.60	3.00
4	.....	6.00	4.60	3.60	2.70	2.30	2.50	2.10	6.10	3.00
5	.....	5.65	4.60	3.50	2.60	2.20	2.30	2.00	5.40	3.00
6	.....	5.50	4.55	3.30	2.60	2.20	2.20	2.00	5.70	2.90
7	.....	5.65	4.35	3.20	2.60	2.50	2.20	2.00	5.20	3.10
8	.....	6.90	4.15	3.00	2.50	2.30	2.10	2.00	4.70	3.10
9	.....	10.50	3.80	3.00	2.50	2.20	2.40	2.10	4.30	3.10
10	.....	11.60	3.70	2.90	2.50	2.20	2.20	2.10	3.90	3.00
11	.....	10.45	3.70	2.90	2.50	2.60	2.10	2.00	7.30	3.00
12	.....	9.15	3.75	2.90	2.40	2.30	2.20	2.00	3.90	3.10
13	.....	8.95	3.80	2.70	2.60	2.40	2.10	2.00	3.70	4.20
14	.....	10.75	3.70	2.70	2.70	2.30	2.10	1.90	4.00	6.80
15	.....	11.55	3.70	2.60	2.60	2.30	2.10	1.90	3.90	7.80
16	.....	11.40	3.60	2.60	2.80	2.30	2.00	1.90	3.80	7.60
17	.....	10.85	3.60	2.60	2.80	2.30	1.90	1.90	3.90	6.70
18	.....	10.05	3.70	2.80	2.70	2.30	1.90	1.90	4.30	6.10
19	.....	9.05	3.60	2.60	2.70	2.30	1.80	1.90	4.40	5.70
20	.....	8.25	3.60	2.50	2.50	2.20	1.80	1.90	4.30	5.40
21	.....	7.75	3.60	2.50	2.50	2.10	1.90	1.90	4.10	5.60
22	.....	7.35	3.80	2.50	2.50	2.10	1.90	1.90	3.80	6.90
23	.....	7.05	3.80	2.50	2.50	2.10	1.80	1.90	3.90	6.30
24	.....	6.65	3.80	2.50	2.50	2.10	1.80	1.90	3.60	6.30
25	10.00	6.20	3.80	2.50	2.50	2.00	1.80	1.90	3.40	6.50
26	9.25	5.85	3.70	2.70	2.40	2.00	1.90	1.90	3.40	7.10
27	8.10	5.70	3.60	2.60	2.40	2.00	1.90	1.90	3.30	6.90
28	7.35	5.65	3.50	2.60	2.40	2.30	1.80	1.80	3.20	6.40
29	7.30	5.35	3.30	2.90	2.40	2.20	1.90	1.90	3.10	5.80
30	7.55	5.10	3.20	3.20	2.40	3.50	2.10	1.90	3.10	5.00
31	7.45	.....	3.20	.....	2.30	3.20	.....	1.90	.....	.....

WEST BRANCH OF SUSQUEHANNA RIVER AT ALLENWOOD, PENNSYLVANIA.

The West Branch of Susquehanna River rises in Cambria County, Pennsylvania, and flows in a general northeasterly direction, meeting the North Branch on the western border of Northumberland County and forming Susquehanna River.

Observations of height of water on the West Branch have been made by the Weather Bureau at Lockhaven, Pennsylvania, 47 miles above Allenwood. The drainage area is given as 3,740 square miles, and the width of river 1,125 feet. The gage is in two sections. The lower section is painted on the side wall of the canal lock, and the upper is on the highway bridge over the river. The elevation of the zero is 555.7 feet. The highest water was 18 feet, on June 1, 1889, and the danger line is at ten feet.

Below the junction of the North and West Branches of Susquehanna River observations have been made of height of water by the Weather Bureau at Selins Grove, 45 miles above Harrisburg. The drainage area is given as 17,600 square miles. The river at this point is about 1 mile wide, including an island 400 feet wide. The gage is on the west abutment of a railroad bridge.

A gaging station was established on the West Branch by E. G. Paul on March 25, 1899, at Allenwood, Pennsylvania, 20 miles above the junction with the North Branch. Measurements are made from the

public highway bridge, one-fourth of a mile east of the railroad station at Allenwood. The wire gage is 42.15 feet from zero to the end of the weight, and is referred to a pine-board scale fastened to iron-work of the bridge and divided into feet and tenths. The initial point of soundings is at the end of the iron guard rail on the right bank. The channel is straight for one-half a mile above and below the station. The current is sluggish, but unobstructed. The banks are low and subject to overflow at time of high water. The bed of the stream is rocky and constant. The observer is Frank L. Allen, a farmer living 200 feet from the gage. The following measurements were made by E. G. Paul during 1899:

March 24, gage height, 4.90 feet; discharge, 32,031 second-feet.
June 8, gage height, 3.00 feet; discharge, 3,988 second-feet.
July 28, gage height, 2.05 feet; discharge, 1,360 second-feet.
September 15, gage height, 1.90 feet; discharge, 1,234 second-feet.
October 17, gage height, 1.70 feet; discharge, 842 second-feet.

Daily gage height, in feet, of West Branch of Susquehanna River at Allenwood, Pennsylvania, for 1899.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	6.70	3.80	3.50	2.90	2.00	2.70	2.00	2.20	2.90
2	.....	6.30	3.80	3.50	2.70	2.00	2.70	2.00	3.60	2.80
3	.....	5.80	3.80	3.40	2.50	2.00	2.70	1.90	4.20	2.70
4	.....	5.35	3.90	3.40	2.50	1.80	2.50	1.90	5.20	2.70
5	.....	5.05	3.80	3.30	2.40	1.70	2.40	1.90	4.60	2.70
6	.....	4.90	3.60	3.20	2.40	1.70	2.30	1.90	4.00	2.60
7	.....	4.80	3.50	3.00	2.30	1.70	2.10	1.90	3.40	2.60
8	.....	6.45	3.30	3.00	2.40	1.70	2.00	1.90	3.20	2.60
9	.....	7.80	3.40	2.90	2.20	1.70	2.00	1.90	3.00	2.60
10	.....	7.40	3.50	2.90	2.00	1.70	2.00	1.80	3.00	2.60
11	.....	6.60	3.60	2.70	2.10	1.70	1.90	1.80	3.00	2.60
12	.....	6.20	3.70	2.60	2.30	1.70	1.90	1.80	3.20	5.30
13	.....	6.50	3.50	2.60	2.20	1.90	1.90	1.70	3.30	8.40
14	.....	7.00	3.40	2.60	2.20	1.90	1.90	1.70	3.40	7.40
15	.....	6.90	3.30	2.50	2.30	1.90	1.90	1.70	3.50	6.50
16	.....	6.80	3.20	2.50	2.20	1.90	1.90	1.70	3.60	5.80
17	.....	6.40	3.40	2.50	2.30	1.90	1.90	1.70	3.80	5.10
18	.....	5.60	3.80	2.40	2.40	1.90	1.90	1.70	3.90	4.90
19	.....	5.40	7.40	2.40	2.60	1.80	1.90	1.70	4.10	4.80
20	.....	5.00	6.50	2.40	2.80	1.70	1.90	1.70	4.30	4.70
21	.....	4.80	5.75	2.40	3.00	1.70	1.90	1.60	4.10	4.30
22	.....	4.70	5.15	2.30	2.70	1.70	1.90	1.60	4.00	4.20
23	4.90	4.50	4.70	2.20	2.50	1.70	1.90	1.60	3.90	4.20
24	4.90	4.40	4.35	2.20	2.30	1.60	1.90	1.60	3.80	5.15
25	4.60	4.30	4.00	2.80	2.20	1.60	1.90	1.60	3.70	7.25
26	4.20	4.30	3.80	2.50	2.20	1.60	1.90	1.60	3.60	5.60
27	4.30	4.30	3.60	2.60	2.10	1.70	2.00	1.60	3.40	5.00
28	6.20	4.20	3.50	2.70	2.00	3.70	2.00	1.60	3.30	4.50
29	6.70	4.30	3.40	2.70	1.90	3.00	2.00	1.60	3.20	4.10
30	7.80	4.10	3.40	2.80	1.80	2.60	2.00	1.60	3.10	3.60
31	7.35	.....	3.50	.....	2.00	2.60	.....	1.60	.....	.....

JUNIATA RIVER AT NEWPORT, PENNSYLVANIA.

Juniata River rises in Center County, Pennsylvania, and flows in a general southeasterly direction into Susquehanna River 15 miles above Harrisburg. Its drainage area is mountainous and for the most part covered with forest growth. The station was established at Newport, about 15 miles above its junction with the Susquehanna,

on March 21, 1899, by E. G. Paul. It is at the covered wagon bridge, 800 feet east of the public square, Newport, Pennsylvania. The wire gage is 39.54 feet long from the end of the weight to the index. A scale board is nailed to the bridge timbers inside of the structure and is divided into feet and tenths. The initial point of soundings is at the end of the woodwork of the bridge on the right bank. The channel is straight for half a mile above and below the station. The current is swift and unobstructed. The banks are high and not subject to overflow. The bed of the stream is rocky and the section constant. The observer is A. R. Bortel, a laborer living in Newport, Pennsylvania, about 800 feet from the gage. The following measurements were made by E. G. Paul during 1899:

March 21, gage height, 6.60 feet; discharge, 13,094 second-feet.
June 9, gage height, 3.20 feet; discharge, 1,903 second-feet.
July 31, gage height, 2.90 feet; discharge, 682 second-feet.
September 14, gage height, 4.55 feet; discharge, 4,625 second-feet.
October 18, gage height, 2.90 feet; discharge, 829 second-feet.

Daily gage height, in feet, of Juniata River at Newport, Pennsylvania, for 1899.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	7.00	3.40	3.11	2.70	3.00	3.50	3.20	2.70	3.30
2	.....	6.10	3.40	3.60	2.70	3.00	3.50	3.10	4.00	3.30
3	.....	5.50	3.60	3.50	2.60	3.00	3.40	3.10	4.90	3.30
4	.....	5.10	3.70	3.40	2.50	3.00	3.40	3.10	4.60	3.30
5	.....	4.90	3.50	3.30	3.00	3.00	3.20	3.00	4.20	3.30
6	.....	4.50	3.40	3.40	3.00	3.00	3.30	3.00	3.90	3.20
7	.....	4.30	3.40	3.30	3.00	3.30	3.30	3.00	3.70	3.10
8	.....	5.60	3.40	3.20	3.00	3.50	3.30	3.00	3.50	3.10
9	.....	7.80	3.60	3.20	3.10	3.30	3.30	2.90	3.50	3.10
10	.....	6.90	3.60	2.80	3.30	3.20	3.30	2.90	3.40	3.10
11	.....	5.80	4.00	2.80	3.30	3.10	3.30	2.90	3.30	3.10
12	.....	5.50	4.10	2.80	3.30	3.10	3.40	2.90	3.30	3.70
13	.....	5.10	4.00	2.80	3.10	3.40	4.80	2.90	3.30	4.80
14	.....	4.90	3.80	2.70	3.10	3.10	4.80	2.90	3.20	5.50
15	.....	4.80	3.80	2.70	3.10	3.10	3.80	2.90	3.20	5.10
16	.....	4.70	3.60	2.70	3.00	3.00	3.50	2.90	3.20	4.80
17	.....	5.50	3.70	2.70	2.90	3.00	3.30	2.90	3.20	4.30
18	.....	4.40	4.10	2.70	2.90	3.00	3.10	2.90	3.10	4.00
19	.....	4.30	8.00	2.60	2.90	3.00	3.10	2.90	3.10	4.00
20	.....	4.10	7.30	2.60	3.00	3.10	3.10	2.90	3.10	3.70
21	6.50	4.00	7.60	2.60	3.00	3.00	3.10	2.90	3.10	3.70
22	6.00	3.90	5.10	2.60	3.00	3.00	3.10	2.90	3.10	5.00
23	5.70	3.80	4.70	2.50	3.00	2.90	3.10	2.80	3.10	5.00
24	6.00	3.80	4.40	2.50	3.00	2.90	3.10	2.80	3.40	5.00
25	5.50	3.70	4.00	2.50	3.00	2.90	3.10	2.80	4.00	5.80
26	5.20	3.60	3.70	2.50	3.00	2.90	3.10	2.80	4.00	5.50
27	5.10	3.60	3.70	2.50	2.80	2.90	3.10	2.80	3.80	4.50
28	5.10	3.60	3.70	2.60	2.90	4.40	3.20	2.80	3.60	4.30
29	8.80	3.50	3.70	2.70	2.90	4.10	3.30	2.80	3.50	4.10
30	10.30	3.40	4.10	2.70	2.90	5.00	3.30	2.70	3.40	4.10
31	8.30	.....	3.11	.....	2.90	4.40	.....	2.70	.....	4.10

SUSQUEHANNA RIVER AT HARRISBURG, PENNSYLVANIA.

Observations of the height of water in the Susquehanna River have been made for several years at the pump house of the waterworks located in the western part of the city of Harrisburg, Pennsylvania, this being about 55 miles below the junction of the north and west branches. A float is located in the pump well connected with the

river, which indicates the height of water upon a painted scale. The datum is the low-water mark of 1804. Observations are made by the engineer, C. M. Nagle, each morning before starting the pumps. The record since 1890 has been furnished by E. Mather, president of the Harrisburg Water Company. Measurements of discharge are made from the open iron bridge on Second street. The initial point for soundings is the iron upright on the east end of the bridge. The stream is divided into two channels, with a large island between. The channel above and below the station is straight for about 2,500 feet, the banks high, and the current of moderate velocity. The first measurement was made on March 31, 1897. The results of measurement may be found as follows: 1897, Nineteenth Annual Report, Part IV, pages 122–127; 1898, Twentieth Annual Report, Part IV, page 109. The following measurements were made by E. G. Paul during 1899:

June 11, gage height, 1.75 feet; discharge, 11,746 second-feet.
July 29, gage height, 0.91 foot; discharge. 6,534 second-feet.
September 12, gage height, 0.75 foot; discharge, 5,404 second-feet.
October 23, gage height, 0.16 foot; discharge, 3,625 second-feet.

Daily gage height, in feet, of Susquehanna River at Harrisburg, Pennsylvania, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.25	2.50	8.41	7.25	3.41	2.50	1.75	0.75	1.83	1.08	0.50	1.75
2	3.16	2.00	8.16	6.41	3.08	2.58	1.66	.75	1.50	.83	1.66	1.58
3	2.75	1.91	7.83	5.83	3.08	2.50	1.66	.75	1.25	.83	2.50	1.50
4	3.25	2.25	7.41	5.33	3.41	2.50	1.50	.75	1.08	.75	3.25	1.50
5	3.50	2.58	8.00	4.91	3.16	2.50	1.33	.75	1.08	.66	4.50	1.50
6	5.00	2.66	12.50	4.41	3.16	2.33	1.25	.91	1.00	.66	3.91	1.50
7	8.00	2.83	13.00	4.25	3.00	2.08	1.25	.75	.91	.58	3.75	1.50
8	6.83	2.41	11.41	4.75	2.75	1.91	1.16	.75	.91	.58	3.16	1.50
9	6.08	2.50	9.25	6.83	2.83	1.91	1.16	.83	.83	.58	2.83	1.50
10	5.41	2.41	7.66	8.75	2.66	1.91	1.16	.75	1.00	.66	2.50	1.50
11	4.58	2.41	6.50	8.41	2.75	1.75	1.41	.66	1.00	.58	2.25	1.50
12	4.00	4.41	5.75	7.75	2.75	1.66	1.25	.66	.75	.58	2.16	1.50
13	3.33	4.41	5.75	6.75	2.91	1.66	1.16	1.08	.83	.50	2.08	2.75
14	3.16	4.58	7.50	6.75	2.83	1.58	1.16	1.08	1.41	.50	2.00	5.50
15	3.33	4.58	8.41	8.00	2.58	1.50	1.16	1.25	1.25	.51	2.25	6.33
16	3.66	4.66	8.00	8.00	2.50	1.50	1.08	.91	.83	.41	2.41	6.00
17	4.83	4.83	7.41	7.83	2.50	1.41	1.00	.66	.75	.41	2.41	5.33
18	7.00	4.83	6.41	7.33	2.58	1.25	1.25	.66	.75	.41	2.41	4.58
19	6.33	4.91	4.33	6.83	3.75	1.25	1.25	.50	.58	.41	2.83	4.08
20	5.66	4.75	7.16	6.00	4.75	1.25	1.25	.50	.66	.33	3.00	3.75
21	4.91	4.91	8.50	5.41	5.16	1.25	1.25	.50	.75	.33	2.91	3.75
22	4.33	5.33	8.16	5.08	4.25	1.16	1.33	.50	.66	.33	2.58	3.83
23	4.25	7.50	7.50	4.91	3.91	1.08	1.33	.50	.66	.33	2.50	4.50
24	4.08	7.50	7.16	4.50	3.58	1.00	1.33	.50	.66	.16	2.25	4.25
25	4.16	7.16	7.41	4.41	3.16	1.41	1.16	.50	.66	.16	2.25	5.83
26	5.25	6.83	7.41	4.00	3.00	2.00	1.00	.41	.66	.25	2.25	6.75
27	4.50	7.33	6.83	3.91	2.91	1.66	1.00	.66	1.00	.33	2.16	5.25
28	3.83	9.00	6.33	3.75	2.66	1.50	1.00	4.00	1.33	.33	2.00	4.58
29	3.25	.....	6.83	3.66	2.50	1.50	.91	2.66	1.16	.41	2.00	3.83
30	3.00	.....	7.83	3.50	2.50	1.75	.83	2.50	1.08	.33	1.83	3.00
31	3.00	.....	8.08	.....	2.50	.....	.75	2.16	.....	.33	.....	2.25

OCTORARO CREEK AT ROWLANDSVILLE, MARYLAND.

This stream rises in Lancaster County, Pennsylvania, and flows in a southwesterly direction between Lancaster and Chester counties into Maryland, where it empties into the Susquehanna River about

five miles below the State line. This station was established November 21, 1896, at the wagon bridge in the village of Rowlandsville, Maryland. The situation is not a good one for making measurements, owing to an eddy along the left bank and the proximity of the mouth of a small tributary, which would cause cross currents in time of high water. The channel is straight, the current swift, the banks high and not subject to overflow. The observations and most of the gagings have been made by Hugh W. Caldwell, of Rowlandsville, Maryland. The record having been continued long enough to have determined the general flow of the stream the station was abandoned September 30, 1899. The following measurements were made by Hugh W. Caldwell during 1899:

Measurements of Octoraro Creek at Rowlandsville, Maryland.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Sec. feet.*	1899.	*Feet.*	*Sec. feet.*
January 24	6.40	1,505	June 28	3.50	185
February 4	4.40	531	June 29	4.00	387
March 15	5.00	666	July 15	3.50	219
March 31	4.80	722	July 28	3.40	186
April 15	4.30	507	August 7	3.50	171
April 21	4.20	470	August 11	5.20	1,044
May 8	4.50	538	August 19	3.40	144
May 20	4.00	413	August 28	3.60	206
June 5	3.80	333	September 25	5.60	1,113
June 16	3.70	189			

Daily gage height, in feet, of Octoraro Creek at Rowlandsville, Maryland, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.
1	4.60	3.90	4.30	4.50	4.00	3.80	3.50	3.35	3.50
2	4.80	4.00	4.45	4.40	4.00	3.80	3.40	3.30	3.45
3	4.95	4.00	4.50	4.20	4.00	3.80	3.40	3.25	3.40
4	4.80	4.30	4.80	4.10	4.00	3.70	3.40	3.30	3.30
5	4.95	4.40	7.45	4.00	4.00	3.70	3.55	3.30	3.20
6	5.45	4.40	6.70	3.90	4.00	3.70	3.90	3.30	3.15
7	5.55	4.30	5.75	5.30	4.00	3.60	3.60	3.55	3.30
8	4.80	4.10	5.15	5.05	4.35	3.75	3.85	3.40	3.20
9	4.55	4.00	4.50	4.85	4.35	3.75	3.85	3.35	3.40
10	4.50	3.90	4.05	4.75	4.05	3.90	3.55	5.90	3.40
11	4.50	3.85	3.80	4.65	4.20	3.75	3.50	3.55	3.45
12	4.30	4.20	3.75	4.30	4.25	3.70	3.45	3.45	3.70
13	4.75	4.85	6.30	4.30	4.05	3.70	3.45	3.45	3.50
14	4.40	5.00	4.60	4.30	4.15	3.70	3.45	3.40	3.40
15	4.30	4.70	5.15	4.30	4.00	3.70	3.50	3.40	3.40
16	4.25	4.65	4.70	4.20	4.05	3.70	3.50	3.40	3.30
17	4.15	7.20	4.40	4.25	4.00	3.65	3.40	3.40	3.30
18	4.00	6.90	4.30	4.20	4.25	3.60	3.55	3.40	3.30
19	3.90	6.80	4.25	4.20	4.05	3.60	3.45	3.40	3.35
20	3.85	6.45	4.20	4.20	4.00	3.60	3.40	3.30	3.85
21	3.70	6.15	4.05	4.20	4.00	3.65	3.35	3.25	3.70
22	3.70	5.75	4.00	4.20	3.95	3.60	3.35	3.40	3.60
23	3.60	5.50	4.00	4.20	3.90	3.50	3.30	3.35	3.35
24	6.30	5.25	3.90	4.10	3.90	3.50	3.35	3.30	3.30
25	6.10	5.05	5.20	4.10	3.85	3.65	3.30	3.30	3.50
26	5.60	5.55	4.70	4.10	3.80	3.65	3.65	3.30	6.30
27	4.90	5.05	4.50	4.00	3.80	3.50	3.65	3.50	4.95
28	4.45	4.55	6.95	4.00	3.80	3.50	3.40	3.55	4.65
29	4.25	.....	5.60	4.00	3.80	3.80	3.40	3.50	4.00
30	4.10	.....	5.00	4.00	3.85	3.60	3.40	3.50	4.15
31	4.05	.....	4.80	.....	3.80	.....	3.40	3.50	.....

Discontinued September 30, 1899.

PATAPSCO RIVER AT WOODSTOCK, MARYLAND.

This river rises in the north-central part of Maryland, flows in a southeasterly direction between Baltimore and Howard counties, and empties into Chesapeake Bay. Its watershed is a hilly country largely under cultivation. A station was established at Woodstock August 6, 1896, by E. G. Paul. The drainage area is 251 square miles and is partly shown on the Ellicott and Frederick sheets of the topographic atlas. Measurements are made from the county bridge on the road from Woodstock to Granite, Maryland, 1½ miles below the junction with the North Branch, as shown on the Ellicott atlas sheet. The scale is a board graduated to feet and tenths with small nails, and fastened to the floor timber of the bridge. The bench mark is a United States Geological Survey standard copper bolt, set in the face of the retaining wall of the entrance to the college grounds at the north end of the bridge. It is 22.06 feet above gage datum. The bridge was repaired on January 20–25, 1899, and the gage destroyed. A new gage was established on January 30, 1899, and referred to the same bench mark. The channel is rough and rocky. The banks are high and not subject to overflow. At a time of extreme high water the channel is liable to changes. The observer is David Donovan, a storekeeper at Woodstock, Maryland. The three following measurements were made by E. G. Paul during 1899: January 30, gage height 4.30 feet, discharge 431 second-feet; May 22, gage height 4.20 feet, discharge 400 second-feet; September 6, gage height 3.60 feet, discharge 129 second-feet.

Daily gage height, in feet, of Patapsco River at Woodstock, Maryland, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	(a)	3.80	4.85	4.65	4.20	3.95	3.75	3.65	3.60	3.55	3.60	3.70
2	(a)	5.10	4.90	4.50	4.15	4.15	3.60	4.30	3.70	3.55	3.75	3.60
3	(a)	5.00	4.70	4.45	4.20	3.95	3.70	4.10	3.80	3.55	3.70	3.20
4	(a)	4.90	4.75	4.35	4.30	3.95	3.75	3.85	3.65	3.40	3.60	3.60
5	(a)	4.90	8.50	4.40	4.15	3.95	4.25	3.85	3.60	3.60	3.70	3.60
6	(a)	5.20	6.70	4.30	4.25	3.95	4.00	3.85	3.45	3.80	3.60	3.65
7	(a)	5.35	5.20	4.60	4.25	3.80	3.90	3.90	3.40	3.75	3.70	3.55
8	(a)	Ice.	4.90	5.90	4.35	3.85	3.90	3.75	3.75	3.60	3.70	3.60
9	(a)	Ice.	4.70	4.65	4.45	3.95	3.90	3.75	3.45	3.70	3.70	3.65
10	(a)	Ice.	4.70	4.65	4.25	4.20	3.95	3.70	3.70	3.70	3.70	3.75
11	(a)	Ice.	4.75	4.45	4.15	4.20	3.75	3.55	3.55	3.65	3.70	3.75
12	(a)	Ice.	4.75	4.50	4.35	4.15	3.65	3.60	3.55	3.55	3.50	4.05
13	(a)	Ice.	4.65	4.20	4.25	4.10	3.80	3.65	3.55	3.45	3.50	3.90
14	(a)	Ice.	4.55	4.35	4.25	4.05	4.05	3.85	3.50	3.50	3.75	3.80
15	(a)	Ice.	4.85	4.40	4.20	3.95	3.80	3.35	3.50	3.70	3.65	3.65
16	(a)	Ice.	4.80	4.45	4.15	4.00	3.80	3.80	3.45	3.65	3.60	3.60
17	(a)	Ice.	4.60	4.45	4.25	4.10	4.15	3.65	3.35	3.65	3.70	3.30
18	(a)	Ice.	4.75	4.40	4.35	4.00	4.15	3.75	3.45	3.65	3.70	3.35
19	(a)	Ice.	5.30	4.30	4.50	3.95	3.95	3.65	3.45	3.60	3.60	3.95
20	(a)	Ice.	4.85	4.30	4.25	3.75	3.80	3.65	3.35	3.70	3.80	3.95
21	(a)	6.20	4.70	4.30	4.20	3.85	3.75	3.65	4.00	3.55	3.75	3.85
22	(a)	5.75	5.00	4.30	4.20	4.00	3.75	3.60	3.45	3.40	3.75	3.80
23	(a)	5.40	4.90	4.25	4.25	3.85	3.70	3.55	3.40	3.40	3.70	3.20
24	(a)	4.95	4.50	4.25	4.20	3.80	3.90	3.50	3.45	3.55	3.65	3.30
25	(a)	5.15	4.40	4.30	4.10	3.80	3.85	3.50	3.55	3.55	3.70	4.40
26	(a)	4.80	4.40	4.25	4.05	3.85	3.90	3.60	5.90	3.60	3.70	3.95
27	(a)	6.15	4.40	4.30	4.00	4.00	3.85	3.65	4.25	3.65	3.65	3.80
28	(a)	5.05	5.30	4.25	4.10	3.85	3.75	3.90	4.00	3.60	3.75	3.85
29	(a)	.....	4.85	4.20	4.00	3.75	3.75	3.90	3.60	3.25	3.70	4.15
30	4.30	.....	4.75	4.20	4.00	3.85	3.50	3.55	3.55	3.60	3.70	4.60
31	3.90	.....	4.65	.....	4.00	.....	3.80	3.65	.....	3.60	.....	.....

a Gage out; no readings.

NORTH BRANCH OF POTOMAC RIVER AT PIEDMONT, WEST VIRGINIA.

This stream rises in the western part of West Virginia and flows in a northeasterly direction, forming the boundary between Maryland and West Virginia. At a point about 15 miles below Cumberland it is joined by the South Branch, forming the Potomac River. The drainage area is mapped on Piedmont, St. George, Accident, Grantsville, and Frostburg atlas sheets. Systematic measurements of discharge have been made at Piedmont, West Virginia. This station, established June 27, 1899, by E. G. Paul, is located at the iron highway bridge connecting Luke, Maryland, with Piedmont, West Virginia. The wire gage is 38.87 feet from index to end of weight, and is referred to a scale board 14 feet long, attached to the bridge 90 feet from the first pier, and is divided into feet and tenths. The channel is straight for an eighth of a mile above and below the station. The current is swift and unobstructed. The right bank is high and rocky, but the left bank is low and liable to overflow. The bed of the stream is rocky and permanent in section. The observer is Charles W. Beck, a bookkeeper at Piedmont, West Virginia. A measurement was made by E. G. Paul on June 27, 1899, at a gage height of 3.00 feet, when the discharge was 350 second-feet.

Daily gage height, in feet, of North Branch of Potomac River at Piedmont, West Virginia, for 1899.

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	3.15	2.50	2.20	2.20	3.75	2.60
2	.....	2.90	2.35	2.20	2.20	3.90	2.60
3	.....	2.80	2.25	2.10	2.15	3.05	2.60
4	.....	2.70	2.40	2.00	2.10	2.80	2.55
5	.....	2.65	2.40	2.30	2.10	2.70	2.50
6	.....	2.70	2.40	2.30	2.10	2.55	2.40
7	.....	2.80	2.55	2.15	2.20	2.50	2.40
8	.....	2.70	2.30	2.10	2.10	2.40	2.40
9	.....	2.70	2.30	2.20	2.15	2.40	2.35
10	.....	2.70	2.25	2.30	2.10	2.40	2.40
11	.....	2.65	2.10	2.95	2.10	2.40	2.50
12	.....	2.50	2.15	3.40	2.20	2.40	5.20
13	.....	2.40	2.10	2.75	2.10	2.30	4.60
14	.....	2.85	2.10	2.45	2.10	2.30	3.75
15	.....	2.85	2.10	2.35	2.00	2.30	3.60
16	.....	2.50	2.00	2.30	2.20	2.30	3.35
17	.....	2.70	2.00	2.30	2.10	2.30	3.05
18	.....	2.90	2.00	2.15	2.10	2.20	3.15
19	.....	2.65	2.00	2.10	2.10	2.40	3.20
20	.....	2.50	2.00	2.45	2.10	3.35	3.70
21	.....	2.35	2.00	2.90	2.10	3.00	3.30
22	.....	.....	1.95	2.65	2.00	2.80	3.20
23	.....	2.30	1.90	2.40	2.00	2.85	3.10
24	.....	2.30	1.90	2.40	2.10	3.30	3.00
25	.....	2.30	1.90	2.25	2.10	3.20	3.00
26	.....	2.20	1.90	2.20	2.10	3.00	2.90
27	3.00	2.15	2.10	2.30	2.10	2.80	2.80
28	2.90	2.50	3.00	2.55	2.10	2.80	2.80
29	3.85	2.35	2.90	2.40	2.20	2.70	2.80
30	3.50	2.30	2.55	2.25	2.15	2.60	2.80
31	.....	2.45	2.35	.....	2.15	.....	2.70

SOUTH BRANCH OF POTOMAC RIVER AT SPRINGFIELD, WEST VIRGINIA.

This stream rises in Highland County, West Virginia, and flows in a northeasterly direction, joining the North Branch of Potomac River about 15 miles below Cumberland, Maryland, forming Potomac River. The drainage area of the South Branch consists of long, narrow, mountain valleys, sparsely settled and little cultivated, being for the greater part covered with timber. The region being free from manufacturing industries and mining operations, no pollution of the waters occurs. The drainage area is mapped on the following atlas sheets: Romney, Piedmont, Beverly, Franklin, Woodstock, Staunton, and Monterey. A gaging station was established at the railroad bridge, 2 miles south of Springfield, West Virginia, in April, 1894, by Cyrus C. Babb, but was discontinued in 1896 for want of an observer. The present station, established June 26, 1899, by E. G. Paul, is located on the iron highway bridge, one-fourth of a mile from Graces Station and 1 mile from Springfield. The wire gage is 39.4 feet from the zero to the extreme end of the weight, and is referred to a scale graduated to feet and tenths, on the guard rail on the upper side of the bridge 80 feet from the abutment on the left bank. The channel of the stream at this point is curved and the current too sluggish to make satisfactory discharge measurements, and they are, therefore, made from the railroad bridge over the stream 1 mile above. The observer is John E. Grace, of Springfield, West Virginia. A measurement was made by E. G. Paul, June 26, 1899, at a gage height of 4.00 feet, when the discharge was 617 second-feet.

Daily gage height, in feet, of South Branch of Potomac River at Springfield, West Virginia, for 1899.

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	3.20	3.40	3.40	3.40	4.60	4.60
2	.....	3.70	3.60	3.40	3.40	4.80	4.10
3	.....	3.70	3.50	3.50	3.40	4.80	4.00
4	.....	3.70	3.40	3.60	3.30	4.80	4.00
5	.....	3.60	3.20	3.60	3.30	4.60	3.80
6	.....	3.60	3.20	3.60	3.20	4.60	3.70
7	.....	3.60	3.20	3.50	3.20	4.50	3.70
8	.....	3.70	3.20	3.50	3.20	4.40	3.50
9	.....	4.20	3.10	3.50	3.20	4.20	3.40
10	.....	3.90	3.10	3.50	3.20	4.10	3.80
11	.....	3.80	3.10	3.40	3.10	4.10	4.00
12	.....	3.60	3.00	3.40	3.10	4.00	5.80
13	.....	3.40	3.00	3.40	3.10	4.00	5.60
14	.....	3.20	3.10	3.40	3.20	4.00	5.60
15	.....	3.10	3.20	3.50	3.20	3.90	5.40
16	.....	3.00	3.20	3.50	3.20	3.80	5.60
17	.....	2.90	3.10	3.50	3.20	3.70	5.60
18	.....	3.00	3.10	3.40	3.20	3.60	5 50
19	.....	3.40	3.00	3.40	3.10	3.60	5.50
20	.....	3.20	3.00	3.40	3.10	3.90	5.40
21	.....	3.20	3.10	3.30	3.10	4.90	5.40
22	.....	3.20	3.20	3.30	3.10	5.90	5.40
23	.....	3.40	3.20	3.20	3.00	5.80	5.00
24	.....	3.50	3.30	3.10	3.00	5.60	4.00
25	.....	3.50	3.30	3.10	3.20	5.60	Ice.
26	4.00	3.40	3.20	3.00	3.40	5.40	Ice.
27	4.20	3.40	3.20	3.00	3.50	5.20	Ice.
28	3.90	3.20	3.10	3.20	3.50	4.80	Ice.
29	4.10	3.20	3.10	3.30	3.80	4.70	Ice.
30	3.40	3.20	3.20	3.40	4.20	4.60	Ice.
31	.....	3.20	3.20	.....	4.40	.....	Ice.

ANTIETAM CREEK AT SHARPSBURG, MARYLAND.

This stream rises in the western part of Maryland and flows in a southerly direction, entering the Potomac 10 miles above Harpers Ferry. Its drainage area is mostly of a hilly character and largely cultivated. A station was established at Myers Mill, 1 mile east of Sharpsburg, Maryland, on the road to Keedysville, Maryland, on June 24, 1897, by Arthur P. Davis. The measurements are made from a three-fourths inch iron cable with 85-foot span, supported by large trees on either side of the stream. The gage is a post driven into the gravel of the stream bed and bolted to an overhanging tree. The initial point for soundings is on the left bank. The channel both above and below the station is straight for 300 feet. The right bank is low and liable to overflow. The left bank is high and rocky. The current is of moderate velocity and the flow unobstructed. The results of measurements may be found as follows: 1897, Nineteenth Annual Report, Part IV, page 149; 1898, Twentieth Annual Report, Part IV, page 122. The following measurements were made by E. G. Paul during 1899: January 27, gage height 2.80 feet, discharge 495 second-feet; May 20, gage height 2.60 feet, discharge 418 second-feet; September 5, gage height 1.80 feet, discharge 118 second-feet.

Daily gage height, in feet, of Antietam Creek at Sharpsburg, Maryland, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.80	2.70	4.75	3.40	2.40	2.40	2.10	1.70	1.80	1.80	2.40	1.60
2	2.70	2.60	4.20	3.30	2.45	3.75	1.90	1.60	1.80	1.80	2.25	1.60
3	2.60	2.60	4.10	3.20	2.90	2.60	2.00	2.55	1.70	1.70	2.00	1.60
4	2.70	2.60	3.85	3.20	2.50	2.60	1.85	1.90	2.00	1.60	1.80	1.50
5	3.00	2.80	4.80	3.10	2.50	2.40	1.90	1.80	1.80	1.60	1.80	1.60
6	3.40	2.80	4.40	3.00	2.50	2.40	1.80	1.70	1.80	1.50	1.90	1.50
7	3.55	2.50	4.05	2.90	2.40	2.30	2.00	1.90	1.70	1.50	1.80	1.50
8	3.20	2.40	3.90	3.25	2.55	2.30	1.90	1.70	1.70	1.50	1.50	1.60
9	3.00	2.60	3.60	3.10	2.70	2.45	1.90	1.70	1.85	1.70	1.60	1.60
10	3.00	2.80	3.50	3.00	2.55	2.70	2.00	1.80	1.60	1.60	1.70	1.50
11	2.90	2.60	3.50	2.90	2.50	2.65	1.90	1.80	2.30	1.50	1.60	1.50
12	2.80	2.80	3.40	2.80	2.50	2.40	1.80	2.35	2.10	1.50	1.70	1.60
13	2.90	2.80	3.30	2.80	2.50	2.40	2.15	1.90	1.85	1.50	1.70	1.60
14	3.00	2.80	3.20	2.80	2.40	2.35	2.00	2.00	1.80	1.50	1.60	1.70
15	3.00	2.90	3.20	2.80	2.30	2.30	1.90	1.90	1.70	1.40	1.60	1.80
16	3.00	2.90	3.50	2.80	2.40	2.30	1.85	1.80	1.60	1.80	1.60	1.80
17	3.00	2.80	3.20	2.70	2.20	2.30	1.95	1.90	1.60	1.70	1.80	1.70
18	3.00	2.90	3.20	2.70	3.15	2.20	1.80	1.80	1.70	1.60	1.70	1.70
19	2.90	2.90	3.70	2.70	2.80	2.25	1.85	1.80	2.00	1.60	1.70	1.60
20	2.80	2.80	3.75	2.60	2.60	2.20	1.80	1.60	1.90	1.60	1.70	1.60
21	2.80	3.20	3.40	2.60	2.50	2.20	1.80	1.80	1.90	1.60	1.70	1.70
22	2.80	4.30	3.40	2.60	2.50	2.10	1.80	1.70	1.80	1.60	1.80	1.60
23	2.80	4.10	3.50	2.50	2.50	2.00	2.05	1.80	1.80	1.70	1.80	1.60
24	2.80	3.70	3.40	2.40	2.40	2.10	1.90	1.70	1.70	1.60	1.70	1.85
25	3.25	3.50	3.30	2.50	2.30	2.05	1.70	1.65	1.90	1.60	1.60	2.65
26	2.90	4.50	3.20	2.45	2.30	2.20	1.75	1.70	1.90	1.50	1.60	1.90
27	2.90	5.40	3.00	2.50	2.30	2.10	1.70	3.45	1.80	1.50	1.70	2.00
28	2.80	5.15	3.50	2.50	2.30	2.15	1.60	2.80	1.80	1.50	1.60	1.90
29	2.80	.....	3.90	2.50	2.20	2.10	1.60	2.30	1.90	1.50	1.70	1.80
30	2.70	.....	3.70	2.40	2.45	2.20	1.60	2.00	1.90	1.60	1.70	1.60
31	2.70	.....	3.50	.....	2.40	.....	1.80	1.90	.....	1.60	.....	.....

NORTH AND SOUTH RIVERS AT PORT REPUBLIC, VIRGINIA.

North and South rivers rise in Rockbridge County, Virginia, and flow in a southeasterly direction, joining at Port Republic to form the

South Fork of the Shenandoah River. The drainage areas of these two rivers are entirely mapped on Franklin, Harrisonburg, Staunton, Buckingham, and Lexington sheets. Systematic measurements are made on the North and South rivers at Port Republic. These stations, described in the Eighteenth Annual Report, Part IV, page 25, were established in August, 1895, by D. C. Humphreys.

The gage for the North River is located on the county highway bridge at Port Republic, Virginia, 500 feet above the mouth of South River. A painted rod is fastened to the third panel of the first span on the lower side of the bridge. It is nailed to the wooden uprights and fastened by wire to the diagonals. Bench mark No. 1, the lower end of the third floor beam from the right bank, is 24.97 feet above zero of the gage. Bench mark No. 2, the bridge seat on lower end of right bank abutment, is 24.60 feet above the datum of the gage.

The gage for South River is located on the county iron bridge just east of the town, 300 feet above the mouth of North River. The graduations of the rod are marked by tacks driven into the rail on the upper side of the bridge at the fourth panel, the zero being 1 foot from the edge of the pulley. Bench mark No. 1, the top of the third floor beam from right bank upper side of bridge, is 22.52 feet above gage datum. The zero of North River gage is 2.56 feet below the zero of South River gage. All gagings of South River include the discharge of mill race. The observer at both gages is T. S. Davis, storekeeper, Port Republic, Virginia. In September, 1898, a new bridge was built to replace the old one, and the stations were soon afterwards abandoned (April 1, 1899), as measurements were made lower down, at Front Royal. Records of measurements may be found as follows: 1895–96, Eighteenth Annual Report, Part IV, pages 25, 26. One measurement was made at each station by E. G. Paul in 1899, as follows: North River, March 11, gage height, 4.80 feet; discharge, 3,423 second-feet. South River, March 11, gage height, 3.70 feet; discharge, 1,592 second-feet.

Daily gage height, in feet, of North River at Port Republic, Virginia, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	Day.	Jan.	Feb.	Mar.	Apr.
1	2.75	2.30	7.10	a3.00	17	2.70	3.00	4.00	.....
2	2.75	2.30	5.50	.....	18	2.70	3.00	3.70	.....
3	2.70	2.30	5.00	.....	19	2.60	3.40	4.00	.....
4	2.65	2.30	7.40	.....	20	2.60	4.00	4.30	.....
5	2.65	2.30	14.00	.....	21	2.60	5.50	3.90	.....
6	5.40	2.30	8.90	.....	22	2.60	7.00	3.60	.....
7	6.70	2.30	7.50	.....	23	2.60	7.60	3.40	.....
8	5.00	2.40	5.80	.....	24	2.60	6.00	3.20	.....
9	4.00	2.40	4.80	.....	25	2.60	4.90	3.10	.....
10	3.60	2.50	5.30	.....	26	2.60	4.90	3.10	.....
11	3.40	2.50	4.80	.....	27	2.60	6.00	3.00	.....
12	3.20	2.50	4.60	.....	28	2.60	9.00	3.00	.....
13	3.00	2.50	4.00	.....	29	2.50	.....	3.00	.....
14	2.90	2.70	3.80	.....	30	2.50	.....	3.00	.....
15	2.80	2.80	4.50	.....	31	2.40	.....	3.00	.....
16	2.80	3.00	4.20	.....					

a Discontinued April 1.

Daily gage height, in feet, of South River at Port Republic, Virginia, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	Day.	Jan.	Feb.	Mar.	Apr.
1	2.50	2.10	4.00	a 2.50	17	2.50	2.60	3.20	.....
2	2.50	2.10	3.60	.....	18	2.40	2.60	2.90	.....
3	2.40	2.10	3.50	.....	19	2.20	2.80	3.20	.....
4	2.30	2.10	5.10	.....	20	2.20	3.00	2.70	.....
5	2.30	2.10	12.00	.....	21	2.20	3.50	3.50	.....
6	3.40	2.10	6.70	.....	22	2.20	5.00	3.20	.....
7	5.00	2.10	5.50	.....	23	2.20	5.60	3.10	.....
8	3.80	2.20	4.00	.....	24	2.20	4.10	2.90	.....
9	3.60	2.20	3.60	.....	25	2.20	3.50	2.80	.....
10	3.00	2.30	3.90	.....	26	2.20	4.40	2.80	.....
11	2.90	2.30	3.70	.....	27	2.20	6.50	2.80	.....
12	2.75	2.30	3.60	.....	28	2.20	5.80	2.70	.....
13	2.60	2.30	3.40	.....	29	2.20	.....	2.70	.....
14	2.60	2.40	3.30	.....	30	2.20	.....	2.60	.....
15	2.60	2.50	3.40	.....	31	2.10	.....	2.50	.....
16	2.60	2.60	3.30	.....					

a Discontinued April 1.

NORTH BRANCH OF SHENANDOAH RIVER AT RIVERTON, VIRGINIA.

This stream rises in Rockingham County, Virginia, and flows in a northeasterly direction, joining with the South Branch of the Shenandoah at Riverton, Virginia. The station was established at Riverton by A. P. Davis June 26, 1899. Measurements were made from an iron-wire cable, about 260 feet in span, stretched across the river on timber supports, 2 miles northwest of Riverton. The station is most easily reached by a private conveyance from Front Royal, Virginia. The gage is a vertical timber, graduated to feet and tenths, bolted to a large sycamore tree on the right bank of the stream. The initial point of soundings is on the right bank. The channel is straight above and below the station for about 600 feet. The banks are low and liable to overflow in time of high water. Bed of stream is rocky and constant. The observer is O. Menefee, a farmer, Riverton, Virginia. Two observations of river height are taken daily. Two measurements were made by E. G. Paul during 1899, both on September 2, with a gage height of 2.85 feet in each case. One measurement was made at the cross section at the point where the cable spans the stream, giving a discharge of 270 second-feet. The other measurement was made by wading, at a better cross section, 300 feet below the regular station, giving a discharge of 287 second-feet.

Daily gage height, in feet, of North Branch of Shenandoah River at Riverton, Virginia, for 1899.

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	2.80	2.68	2.88	2.70	3.20	.....
2	.....	2.80	2.68	2.88	2.68	2.95	.....
3	.....	2.78	2.68	2.95	2.60	2.95	2.65
4	.....	2.80	2.70	2.85	2.65	2.95	2.65
5	.....	2.73	2.65	2.78	2.70	2.85	2.63
6	.....	2.73	3.00	2.73	2.68	2.80	2.60
7	.....	2.80	2.95	2.78	2.65	2.80	2.63
8	.....	2.80	2.95	2.70	2.65	2.80	2.65
9	.....	2.80	2.83	2.70	2.68	2.80	2.60
10	.....	2.80	2.80	2.70	2.70	2.80	2.63
11	.....	2.80	2.73	2.70	2.70	2.78	2.65
12	.....	2.78	2.70	2.73	2.70	2.75	2.68
13	.....	2.75	2.70	2.73	2.70	2.73	2.80
14	.....	2.75	2.73	2.70	2.70	2.70	2.85
15	.....	2.70	2.70	2.70	2.70	2.70	2.90
16	.....	2.68	2.78	2.68	2.65	2.70	2.90
17	.....	2.68	2.78	2.70	2.65	2.70	2.90
18	.....	2.78	2.78	2.68	2.70	2.70	2.90
19	.....	2.75	2.70	2.60	2.68	2.70	2.88
20	.....	2.70	2.65	2.80	2.70	2.70	2.80
21	.....	2.68	2.63	2.80	2.65	2.70	2.80
22	.....	2.68	2.63	2.80	2.65	2.70	2.80
23	.....	2.65	2.68	2.80	2.65	2.70	2.80
24	.....	2.58	2.65	2.80	2.65	2.70	2.80
25	.....	2.63	2.63	2.80	2.70	2.70	2.83
26	2.85	2.70	2.65	2.80	2.70	.....	2.88
27	2.88	2.68	2.63	2.78	2.70	.....	3.00
28	2.88	2.85	2.70	2.75	2.70	.....	3.00
29	2.88	3.13	2.68	2.70	2.70	.....	3.00
30	2.80	2.80	2.95	2.70	2.68	.....	3.00
31	.....	2.70	2.90	.....	2.75	.....	.....

SOUTH BRANCH OF SHENANDOAH RIVER AT FRONT ROYAL, VIRGINIA.

This stream rises in Augusta County, Virginia, and flows in a northeasterly direction, joining the North Branch of the Shenandoah at Riverton to form Shenandoah River. A station was established on the South Branch by A. P. Davis, June 26, 1899. The measurements of flow are made from an iron wire cable 300 feet in span, stretched across the stream 3 miles southwest of Front Royal, Virginia. The gage is a vertical timber divided into feet and tenths and bolted to the trunk of a tree on the left bank of the stream. The initial point for sounding is on the left bank. The channel is straight 600 feet above and below the station, and the current sluggish. The left bank is low and liable to overflow. The bed of the stream is rocky in part, with patches of sand somewhat shifting. The observer is Miss Brentie Johnson, Front Royal, Virginia. One measurement of discharge was made by E. G. Paul, September 1, 1899; gage height, 4.40 feet; discharge, 616 second-feet.

Daily gage height, in feet, of South Branch of Shenandoah River at Front Royal, Virginia, for 1899.

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	4.30	4.40	4.40	4.45	5.50	4.40
2	.....	4.30	4.35	4.35	4.40	8.05	4.40
3	.....	4.20	4.20	4.30	4.30	6.70	4.30
4	.....	4.20	4.25	4.20	4.30	5.85	4.30
5	.....	4.10	4.25	4.50	4.30	5.80	4.20
6	.....	4.20	4.20	4.30	4.30	5.65	4.20
7	.....	4.20	4.30	4.20	4.30	5.35	4.20
8	.....	4.25	4.65	4.15	4.35	5.20	4.20
9	.....	4.55	4.30	4.25	4.40	5.05	4.30
10	.....	4.70	4.50	4.75	4.40	4.85	4.30
11	.....	4.30	4.45	4.65	4.40	4.80	4.30
12	.....	4.20	4.30	4.55	4.40	4.70	4.45
13	.....	4.15	4.20	4.45	4.30	4.70	6.95
14	.....	4.20	4.20	4.40	4.30	4.60	6.25
15	.....	4.15	4.20	4.30	4.30	4.60	5.75
16	.....	4.25	4.30	4.30	4.20	4.55	5.45
17	.....	4.15	4.35	4.30	4.20	4.50	5.25
18	.....	4.15	4.25	4.20	4.20	4.50	5.15
19	.....	4.15	4.30	4.20	4.20	4.50	5.00
20	.....	4.10	4.25	4.55	4.20	4.50	4.95
21	.....	4.10	4.20	5.80	4.10	4.50	4.85
22	.....	4.10	4.10	5.30	4.15	4.40	4.75
23	.....	4.15	4.10	4.85	4.20	4.40	4.70
24	.....	4.10	4.00	4.60	4.20	4.50	4.90
25	.....	4.10	3.90	5.00	4.20	4.50	4.90
26	4.40	4.05	4.00	4.60	4.20	4.55	5.10
27	4.30	4.10	4.00	4.55	4.20	4.50	5.10
28	4.25	4.20	4.30	4.60	4.20	4.40	5.00
29	4.35	4.30	5.15	4.50	4.20	4.40	5.00
30	4.30	4.80	5.05	4.50	4.20	4.40	5.15
31	.....	4.25	4.60	.....	4.20	.....	.....

SHENANDOAH RIVER AT MILLVILLE, WEST VIRGINIA.

This river, formed by the junction of the North Fork and the South Fork at Riverton, Virginia, flows in a northeasterly direction into West Virginia, where it empties into the Potomac at Harpers Ferry.

Observations of the height of Potomac River at the junction of Shenandoah River have been made by the Weather Bureau at Harpers Ferry, West Virginia. The gage is on the west face and north end of the second abutment of the old railroad bridge from the West Virginia side of the river. It is of Portland cement, 15 inches wide, plastered on the face of the pier extending to 32 feet, and continued on the iron upright of the bridge to 36 feet. The top surface of the 6-by-6-inch-square capstone corresponds to the 32-foot mark on the gage. The elevation is 235.5 feet above mean sea level.

A station was established at Millville, West Virginia, April 15, 1895, on Shenandoah River, 4 miles above its mouth. A vertical gage was placed in the river and fastened to a tree, a deep notch being cut in the tree opposite the 8-foot mark. This gage is referred to a bench mark consisting of a copper bolt driven in the foot of a large sycamore tree on the left bank of the river 150 feet below the gage rod, at an elevation of 6.78 feet above the zero mark on the gage. Measurements are made from a cable stretched across the river. The old cable was carried away by the flood of 1896, and a new three-fourths

inch galvanized iron wire cable was put in place on June 23, 1897. The cable, about 500 feet in length, is supported on either bank by a large sycamore tree, and is securely anchored on both sides. The channel is straight, current swift and unobstructed. The banks are low and subject to overflow. The observer is W. R. Nicewarner. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 28; 1897, Nineteenth Annual Report, Part IV, page 151; 1898, Twentieth Annual Report, Part IV, page 127. The following measurements were made by E. G. Paul during 1899:

January 27, gage height, 2.40 feet; discharge, 3,156 second-feet.
March 10, gage height, 5.00 feet; discharge, 10,838 second-feet.
May 16, gage height, 2.10 feet; discharge, 2,753 second-feet.
September 3, gage height, 0.90 foot; discharge, 1,086 second-feet.
October 29, gage height, 0.60 foot; discharge, 766 second-feet.

Daily gage, height in feet, of Shenandoah River at Millville, West Virginia, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.50	2.30	Ice.	3.10	1.70	2.05	0.90	1.00	1.10	0.80	1.55	0.80
2	2.20	2.10	Ice.	3.00	1.60	2.35	.90	.80	.90	.70	2.75	.80
3	2.80	1.70	Ice.	2.80	1.60	3.00	.80	.90	.90	.70	3.26	.75
4	2.60	2.00	Ice.	2.70	1.60	2.10	.80	1.30	1.10	.70	2.40	.70
5	3.30	2.40	Ice.	2.60	2.00	1.80	.80	.90	.80	.70	1.90	.75
6	3.80	2.50	Ice.	2.50	1.90	1.50	.80	.80	.70	.70	1.80	.70
7	4.60	2.30	Ice.	2.40	1.90	1.40	.70	1.10	.80	.70	1.60	.70
8	6.70	2.50	Ice.	2.50	1.80	1.40	.80	1.00	.70	.70	1.40	.70
9	5.00	2.50	Ice.	3.10	2.00	1.50	.90	1.20	.70	.80	1.30	.70
10	4.50	2.30	5.00	3.00	2.30	1.40	1.00	1.00	.70	.80	1.20	.70
11	3.80	2.40	5.50	2.90	3.10	1.30	.90	1.60	.80	.70	1.10	.70
12	3.50	(a)	5.20	2.70	2.80	1.40	.80	.90	1.20	.80	1.00	.75
13	3.30	(a)	4.60	2.60	2.60	1.40	.80	.80	.90	.70	1.00	.90
14	3.00	2.30	4.00	2.50	2.70	1.30	.70	.90	.80	.70	1.00	2.90
15	2.90	2.40	4.00	2.40	2.20	1.30	.70	.80	.80	.70	.90	2.20
16	3.00	2.50	4.00	2.30	2.10	1.30	.90	.70	.70	.60	.90	1.90
17	2.90	2.70	4.50	2.20	1.90	1.20	.80	.80	.70	.60	.90	1.60
18	2.90	3.00	3.90	2.20	1.90	1.10	.70	.80	.60	.60	.80	1.40
19	2.90	3.00	3.80	2.20	2.50	1.00	.70	.80	.60	.60	.90	1.30
20	2.80	3.40	3.80	2.20	2.30	1.00	.70	.70	.80	.60	.80	1.20
21	2.60	4.00	3.80	2.20	2.00	1.00	.70	.70	.90	.60	.80	1.20
22	2.40	Ice.	3.70	1.90	1.90	.90	.70	.60	.90	.60	.80	1.10
23	2.40	Ice.	3.50	1.90	1.70	1.00	.60	.60	1.50	.60	.80	1.10
24	2.40	Ice.	3.30	1.90	1.70	.90	.60	.60	1.10	.60	.80	1.10
25	2.40	Ice.	3.10	1.80	1.60	.90	70	.50	1.00	.60	.80	1.30
26	2.30	Ice.	3.00	2.00	1.50	.90	.60	.50	.90	.50	.85	1.20
27	2.50	Ice.	2.90	1.90	1.50	.90	.60	.60	.90	.60	.85	1.70
28	2.30	Ice.	2.90	1.80	1.40	.90	.60	.70	.90	.60	.80	1.40
29	2.20	.....	3.00	1.80	1.40	.90	.60	.80	.80	.60	.80	1.65
30	2.10	.....	3.60	1.70	1.30	1.00	1.50	1.00	.80	.60	.80	1.10
31	2.10	.....	3.30	.....	1.60	.....	1.00	1.30	.....	.70	.....	1.10

a No readings.

POTOMAC RIVER AT POINT OF ROCKS, MARYLAND.

This station was established February 17, 1895, as described in Bulletin 140, page 54. It is about 6 miles above the mouth of Monocacy River, and also above a number of smaller streams, and therefore the measurements of discharge do not represent the entire flow of

Potomac River. The drainage area here is estimated to be 9,654 square miles. It is largely mapped on topographic atlas sheets—Harpers Ferry, Winchester, Romney, Piedmont, Warrensburg, Luray, Woodstock, Franklin, Beverly, Harrisonburg, Staunton, Monterey, Buckingham, and Lexington. Catoctin Creek enters the Potomac 1,000 feet above the station. The measurements are made from the highway bridge at Point of Rocks. The wire gage is on the east side of the first span, the scale being marked on the hand rail of the bridge. The gage is referred to two bench marks—one, a copper bolt in a large capstone on the lower wing wall of the north abutment, about 10 feet from the north end of the first iron truss, is 41.30 feet above the datum of the gage. The length of the wire gage is 44.22 feet. The gage was verified on October 29, 1899. The observer is G. H. Hickman. The records of flow may be found as follows: 1895–96, Eighteenth Annual Report, Part IV, page 32; 1897, Nineteenth Annual Report, Part IV, pages 152–153; 1898, Twentieth Annual Report, Part IV, page 131. The following measurements were made by E. G. Paul during 1899:

January 28, gage height, 3.80 feet; discharge, 17,330 second-feet.
May 20, gage height, 8.15 feet; discharge, 45,986 second-feet.
September 5, gage height, 0.80 foot; discharge, 2,360 second-feet.
October 29, gage height, 0.50 foot; discharge, 1,628 second-feet.

Mr. William Rich Hutton, of 35 Broadway, New York, states that in the summer of 1856 he made a careful examination of the flow of Potomac River a short distance below the Great Falls, using loaded poles reaching as near as possible to the bottom and placed at 5-foot intervals across the width of the river. The water was then at the lowest stage known to persons who had observed the river for many years. The discharge was 1,063 second-feet. Mr. Hutton was of the opinion that the river was as low in 1862, but no measurements were made in that year.

In 1839 a civil engineer, Mr. M. C. Ewing, assistant to Major Turnbull, United States topographic engineer, during the construction of the Alexandria Aqueduct above Georgetown, reported the discharge below Little Falls to be 1,904 second-feet. Mr. Thomas L. Patterson, of Cumberland, is reported to have found the discharge at that point in the low water of 1838 to be 24 second-feet, and at Patterson Creek, some 12 miles below, 48 second-feet. Figures of discharge of Potomac River are given in the statement regarding the extension of the Chesapeake and Ohio Canal in House Ex. Doc. No. 208, Forty-third Congress, first session; also in House Ex. Doc. No. 137, Forty-fourth Congress, first session.

Daily gage height, in feet, of Potomac River at Point of Rocks, Maryland, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.00	2.40	11.90	5.30	1.60	2.00	1.00	0.70	0.90	0.70	0.80	0.80
2	3.40	2.00	9.20	4.50	1.60	2.40	1.00	.70	.90	.60	1.50	.80
3	2.90	2.10	8.20	4.00	2.10	3.80	1.10	.70	.80	.60	2.50	.80
4	2.70	2.10	7.60	3.60	1.70	2.60	1.00	.90	.80	.60	2.00	.80
5	2.30	2.00	8.50	3.30	1.70	2.10	.90	1.00	.80	.60	1.80	.80
6	4.10	2.00	16.55	3.00	2.10	1.80	1.00	1.10	.70	.60	1.40	.70
7	6.90	2.00	12.90	2.80	2.00	1.60	2.00	1.10	.70	.70	1.40	.70
8	8.10	2.30	10.00	3.00	1.90	1.50	1.00	1.10	.60	.70	1.30	.70
9	6.80	2.30	8.10	3.50	2.00	1.40	1.00	1.00	.60	.70	1.20	.70
10	5.40	3.60	6.00	3.40	2.40	1.70	.90	1.00	.60	.60	1.00	.70
11	4.60	4.20	5.80	4.20	4.50	1.80	.90	.90	.60	.60	.90	.70
12	3.90	4.20	5.60	4.50	3.80	1.70	.80	.80	.80	.60	.90	.80
13	3.60	4.00	5.00	3.40	3.40	1.70	.80	.60	1.20	.60	.80	.80
14	3.40	3.90	4.80	3.20	3.20	1.60	.80	.60	1.10	.50	.80	1.20
15	3.40	3.80	4.50	3.00	2.80	1.50	.90	.60	1.00	.50	.80	3.00
16	4.00	4.00	4.60	2.80	2.50	1.50	1.10	.70	.90	.50	.80	2.10
17	5.70	4.50	4.70	2.70	2.30	1.40	.90	.70	.80	.50	.80	1.70
18	5.20	5.00	4.40	2.60	2.40	1.40	.70	.60	.70	.50	.70	1.50
19	4.70	5.20	5.20	2.50	8.55	1.30	.70	.60	.70	.50	.70	1.60
20	4.40	5.40	5.40	2.40	6.30	1.30	.70	.60	.90	.50	.70	1.50
21	4.00	6.00	5.30	2.20	5.00	1.20	.70	.60	.70	.50	.70	1.30
22	3.50	8.50	4.70	2.10	3.60	1.20	.70	.50	.80	.50	.70	1.10
23	3.30	14.80	4.20	2.00	3.00	1.10	.70	.50	.90	.50	.80	1.00
24	3.20	13.70	4.00	2.00	2.70	1.10	.60	.50	.90	.50	.80	1.20
25	3.30	9.00	3.90	2.00	2.40	1.00	.60	.50	.90	.50	.90	1.80
26	4.80	6.00	3.70	1.90	2.10	1.00	.60	.50	1.00	.50	.90	2.10
27	4.70	9.25	3.50	1.90	2.00	1.00	.60	1.20	.80	.50	.80	1.60
28	3.90	13.80	3.40	1.80	1.80	1.20	.60	1.10	.70	.50	.80	1.50
29	3.20	.....	3.60	1.70	1.70	1.10	.50	1.10	.70	.50	.80	1.60
30	2.80	.....	8.60	1.70	1.70	1.00	.80	1.00	.80	.50	.80	1.60
31	2.60	.....	7.00	.....	1.80	.....	.80	1.00	.....	.60	.....	1.60

MONOCACY RIVER AT FREDERICK, MARYLAND.

Monocacy River rises in the south-central part of Pennsylvania and flows in a southerly direction through Frederick County, Maryland, entering Potomac River near the Montgomery County line. A station was established by E. G. Paul, August 4, 1896, at the county iron bridge on the turnpike, 4 miles northeast of Frederick, on the road leading from Frederick to Mount Pleasant, Maryland, and about 2,000 feet above the mouth of Israel Creek and 3,000 feet below the mouth of Tuscarora Creek, as shown on the Frederick atlas sheet. The drainage area is 665 square miles at this point and 1,000 square miles at the mouth. The gage is attached to the floor timber on the lower side of the bridge. The length of the wire is 35.20 feet. The bench mark is a cross cut in the top face of the capstone on the lower retaining wall of the bridge abutment on the right bank of the stream, and is 29.17 feet above gage datum. The stream at this station has two channels, being divided by a small, low island, which serves as a foundation for the middle pier of the bridge. The right channel is measured from the lower side of the bridge, and the left channel from the upper side, as these sections are freer from rocks than a continuous section on either side of the bridge. The stream is subject to high water and sudden floods, owing to the character of its upper watershed. The observer is E. L. Derr, a farmer near Frederick, Maryland. Records of measurement can be found as follows:

1896, Eighteenth Annual Report, Part IV, page 35; 1897, Nineteenth Annual Report, Part IV, pages 153–155; 1898, Twentieth Annual Report, Part IV, page 129. Two measurements were made by E. G. Paul during 1899. The first, May 22, at a gage height of 5.20 feet, when the dischage was 633 second-feet. The second one was on September 6, at a gage height of 4.00 feet, with a discharge of 153 second-feet.

Daily gage height in feet of Monocacy River at Frederick, Maryland, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	5.40	5.20	11.50	7.10	4.80	7.10	4.10	3.90	4.30	4.00	7.30	4.10
2	5.00	5.20	10.10	6.90	4.80	11.10	4.10	4.00	4.30	3.90	6.40	4.10
3	5.50	5.80	9.20	6.50	5.00	7.05	4.10	5.10	5.40	3.90	6.30	4.10
4	6.00	5.60	8.70	6.10	4.90	5.20	4.00	5.00	5.00	3.90	6.00	4.10
5	6.30	5.90	17.15	6.00	4.90	4.90	4.00	5.00	4.50	3.80	5.30	4.10
6	12.75	5.70	11.45	6.00	4.80	4.70	4.50	4.90	4.00	3.80	5.00	4.00
7	14.85	5.50	8.90	7.60	4.80	4.50	4.40	4.50	3.90	3.90	4.50	4.00
8	12.50	5.40	7.80	12.60	5.20	4.50	4.20	4.00	3.80	3.90	4.40	3.90
9	10.20	6.00	7.50	8.50	6.60	5.50	4.30	4.00	3.70	4.10	4.30	3.90
10	6.10	6.00	7.40	6.90	5.60	6.85	4.20	4.00	4.00	4.10	4.30	3.90
11	6.10	6.00	7.40	6.50	5.40	6.90	4.20	4.00	4.00	4.00	4.20	3.90
12	5.70	6.00	7.30	6.20	5.80	6.50	4.10	4.20	3.90	4.00	4.10	4.80
13	5.80	6.00	7.10	5.90	5.40	5.20	4.30	4.00	3.90	3.90	4.10	5.95
14	6.00	6.00	6.50	5.60	5.00	4.90	4.20	3.90	3.80	3.90	4.10	5.50
15	6.80	6.00	6.50	5.60	5.00	6.20	4.20	3.90	3.80	3.90	4.10	4.50
16	6.60	6.00	9.70	5.60	4.90	5.10	4.50	3.90	3.80	3.90	4.10	4.40
17	6.60	6.20	6.90	5.60	5.20	4.80	4.30	3.90	3.70	3.90	4.10	4.40
18	7.10	6.80	7.90	5.60	6.50	4.50	4.30	3.80	3.70	4.00	4.10	4.30
19	6.40	7.90	13.90	5.60	7.70	4.40	4.20	3.80	3.70	3.90	4.10	4.20
20	5.60	9.00	10.10	5.40	6.90	4.40	4.10	3.80	6.00	3.90	4.10	4.20
21	5.60	12.50	7.90	5.20	6.50	4.40	4.00	3.80	5.30	3.80	4.10	4.50
22	5.60	13.50	7.80	5.10	5.20	4.30	3.90	3.80	5.00	3.80	4.10	4.40
23	5.60	15.65	7.60	5.10	5.20	4.30	3.90	3.80	4.90	3.80	4.10	4.30
24	5.70	11.60	7.20	5.00	5.00	4.30	3.90	3.80	4.50	3.80	5.30	7.10
25	10.40	9.10	6.70	5.00	4.90	4.20	4.30	3.80	4.30	3.80	4.70	6.90
26	8.20	9.10	6.70	5.00	4.80	4.20	4.50	3.80	5.25	3.80	4.40	6.20
27	6.50	17.80	6.70	5.00	4.70	4.20	4.40	4.70	5.50	3.80	4.30	6.00
28	5.20	12.50	10.15	4.90	4.70	4.20	4.30	4.95	5.30	3.80	4.30	5.10
29	5.20	.....	11.00	4.90	4.60	4.20	4.20	4.70	5.00	3.80	4.30	5.10
30	5.20	.....	8.10	4.80	5.00	4.20	4.00	4.30	4.50	3.80	4.20	5.10
31	5.20	.....	7.90	.....	5.00	.....	3.90	4.30	.....	5.00	.....	.....

ROCK CREEK AT ZOOLOGICAL PARK, DISTRICT OF COLUMBIA.

This creek rises in Montgomery County, Maryland, and flows in a southerly direction through the District of Columbia, emptying into Potomac River. A study of the discharge of Rock Creek was begun in 1892, at the request of the Commissioners of the District of Columbia, and a gage rod established by Cyrus C. Babb at Lyons Mill. In August, 1892, a self-registering gage was placed at the bridge, and the record continued until November 30, 1894. The present station was established January 18, 1897, by E. G. Paul, at the bridge of the National Zoological Park, District of Columbia. The upper part of the gage is vertical and is fastened to the bridge abutment, the lower part being inclined and fastened to the iron rods. The bench mark consists of a cross cut in the stone of the bridge pier. It is 9.13 feet above the zero of the gage. The observer is W. V. Kramer, a park watchman.

Daily gage height in feet of Rock Creek at Zoological Park, District of Columbia, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.05	2.78	3.80	3.00	2.75	2.88	2.40	2.35	2.40	2.58	3.65	2.53
2	2.75	2.88	3.23	2.93	2.70	2.68	2.40	2.35	2.40	2.50	2.83	2.58
3	2.88	2.88	3.13	2.90	2.73	2.63	2.35	3.90	2.40	2.50	2.80	2.53
4	2.90	2.95	3.10	2.90	2.70	2.60	2.35	3.20	2.40	2.50	3.10	2.50
5	3.33	3.13	4.50	2.90	2.70	2.55	2.60	2.65	2.38	2.50	2.80	2.50
6	3.60	3.00	3.40	2.90	2.70	2.55	2.58	2.90	2.30	2.75	2.70	2.50
7	4.25	3.00	3.18	2.95	2.75	2.55	2.70	2.55	2.30	2.70	2.63	2.50
8	3.23	2.93	3.10	3.80	2.75	2.55	2.50	2.50	2.30	2.58	2.60	2.50
9	3.05	2.63	3.10	3.08	3.23	2.50	2.78	2.48	2.30	2.60	2.60	2.50
10	3.00	2.98	3.08	3.00	2.83	3.63	2.48	2.53	2.30	2.58	2.60	2.50
11	3.00	2.78	3.23	2.90	2.83	2.98	2.43	2.50	2.40	2.55	2.60	2.50
12	3.10	2.78	3.18	2.90	2.98	2.73	2.40	2.48	2.43	2.50	2.58	2.78
13	2.90	2.78	3.13	2.90	2.78	2.65	2.50	2.45	2.30	2.50	2.55	2.75
14	3.00	2.78	3.00	2.90	2.73	2.63	2.70	2.75	2.30	2.50	2.55	2.63
15	3.00	2.95	3.10	2.85	2.70	2.55	2.45	2.50	2.30	2.50	2.55	2.53
16	3.00	2.95	3.30	3.05	2.68	2.50	2.45	2.70	2.25	2.50	2.55	2.50
17	3.10	4.00	3.00	3.00	2.73	2.50	2.90	2.50	2.25	2.50	2.55	2.50
18	3.08	4.25	3.05	2.90	3.25	2.50	2.58	2.45	2.30	2.50	2.55	2.55
19	2.98	4.43	3.90	2.85	2.95	2.50	2.45	2.43	2.43	2.50	2.58	2.60
20	2.93	4.05	3.33	2.85	2.78	2.50	2.40	2.40	3.00	2.50	2.55	2.60
21	3.13	3.88	3.10	2.80	2.70	2.48	2.40	2.40	2.63	2.50	2.55	2.60
22	2.85	4.18	3.18	2.80	2.70	2.45	2.40	2.73	2.55	2.45	2.55	2.55
23	2.85	4.10	3.18	2.80	2.68	2.45	2.40	2.45	2.40	2.45	2.60	2.50
24	2.85	3.50	3.08	2.80	2.65	2.45	2.40	2.35	2.35	2.48	2.63	2.93
25	3.68	3.20	3.00	2.80	2.60	2.48	2.40	2.30	2.65	2.45	2.60	2.95
26	3.08	3.15	3.00	2.80	2.60	2.53	2.50	2.30	5.25	2.45	2.60	2.68
27	3.00	3.70	3.00	2.83	2.60	2.50	2.50	2.55	3.75	2.50	2.55	2.53
28	2.88	3.33	3.23	2.78	2.60	2.48	2.40	2.75	2.85	2.50	2.55	2.60
29	2.85	.....	3.45	2.75	2.65	2.45	2.40	2.48	2.60	2.50	2.55	2.53
30	2.83	.....	3.15	2.75	2.60	2.43	2.40	2.40	2.60	2.50	2.55	2.53
31	2.85	.....	3.08	.....	2.60	.....	2.38	2.40	.....	2.63	.....	2.50

NORTH ANNA RIVER, VIRGINIA.

Measurements of North Anna River, a tributary of Pamunkey River, were made in August, 1896, by J. O. Smith and A. Langstaff Johnston, of Richmond, Virginia, at Mr. Smith's mill, at a point about 1 mile above the Hanover County line; also at McGeehees Bridge, about 3 miles above the mill. At that time the river was at its lowest stage for the year. During the winter the volume is believed to be four or five times greater. The measurements at the mill gave an average area of 148 square feet and an average velocity of 0.69 foot per second, the total discharge being 102 second-feet. The measurements at McGeehees Bridge showed an average area of 184 square feet and an average velocity of 0.50 foot per second, giving a discharge of 92 second-feet.

NORTH RIVER AT GLASGOW, VIRGINIA.

This river rises on the western slope of the Shenandoah Mountains, and flows in a southeasterly direction across the valley between the Shenandoah and Blue Ridge ranges, emptying into James River about 17 miles south of Lexington, Virginia. Its watershed is largely under cultivation, except in the upper part, where it is mountainous and covered with forest growth. The entire drainage area is mapped on the Lexington, Monterey, Staunton, and Natural Bridge atlas sheets. This station was established at the East Glasgow County Bridge,

about 1 mile above the mouth of North River, by C. C. Babb and D. C. Humphreys, on August 21, 1895. The height of water is observed by means of a wire gage, the board being placed on the guard rail on the lower side of the bridge, and graduated in feet and tenths. This gage is referred to a bench mark at the top of the top chord of the bridge over the gage pulley at an elevation of 32.24 feet. The distance from the end of the weight to the marker of the gage is 27.86 feet. The measurements of discharge are made from the bridge, the initial point for soundings being on the left bank. The channel is straight for about 200 feet above and below the station; the current rather sluggish, but with sufficient velocity for measurements. There is a dam on the North River 10 miles above the station, but its influence on the flow is scarcely noticeable. The right bank is high, but the left bank is subject to overflow in very high water. The bed is of rock and gravel, and fairly permanent. The observer is B. G. Baldwin, a merchant of Glasgow, Virginia. Results of measurements may be found as follows: 1895–96, Eighteenth Annual Report, Part IV, page 38; 1897, Nineteenth Annual Report, Part IV, page 162; 1898, Twentieth Annual Report, Part IV, page 135. The following discharge measurements were made during 1899 by D. C. Humphreys:

March 30, gage height, 2.82 feet; discharge, 2,039 second-feet.

June 27, gage height, 0.95 foot; discharge, 227 second-feet.

August 7, gage height, 0.92 foot, discharge 218 second-feet.

At this last measurement the velocity was barely sufficient to turn the meter and surface floats indicated that the discharge should be somewhat greater.

Daily gage height, in feet, of North River at Glasgow, Virginia, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.05	1.80	(a)	2.60	1.42	1.38	0.90	0.72	0.85	0.95	2.50	0.73
2	2.10	1.72	(a)	2.43	1.42	1.48	.80	.72	.82	.90	1.50	.75
3	2.00	1.80	(a)	2.35	1.43	1.40	.82	.73	.82	.85	1.35	.78
4	2.30	2.30	(a)	2.20	1.42	1.30	.80	.75	.82	.85	1.25	.76
5	2.52	b2.80	13.05	2.15	1.42	1.25	.80	.75	.80	.85	1.29	.76
6	4.01	3.30	(a)	2.10	1.48	1.21	.78	.75	.71	.85	1.10	.78
7	7.00	3.15	(a)	2.10	1.52	1.15	.80	.90	.71	.84	1.05	.75
8	b5.38	2.80	(a)	2.80	1.62	1.12	.80	.80	.70	.87	1.00	.78
9	3.75	2.30	(a)	2.55	3.75	1.10	.80	.73	1.10	.98	.95	.78
10	3.30	2.30	(a)	2.42	2.85	1.10	.95	.73	1.00	.90	.93	.75
11	2.95	2.28	(a)	2.35	2.45	1.08	.88	.72	.90	.85	.92	.73
12	2.60	b2.27	(a)	2.30	1.85	1.30	.80	.72	1.00	.82	.92	1.25
13	2.45	2.26	(a)	2.22	2.30	1.40	.80	.73	.95	.80	.92	2.10
14	2.45	2.25	(a)	2.12	2.25	1.30	.80	.77	.90	.75	.84	1.85
15	2.38	2.25	(a)	2.10	2.15	1.20	.80	1.92	.80	.70	.80	1.50
16	2.35	2.26	(a)	2.00	2.00	1.20	.80	1.10	.75	.65	.80	1.42
17	2.28	2.30	(a)	1.94	1.90	1.18	.80	.88	.73	.68	.83	1.25
18	2.25	2.45	(a)	1.90	1.80	1.10	.80	.80	.72	.68	.80	1.12
19	2.20	2.75	(a)	1.82	1.80	1.02	.75	.72	.72	.70	.65	1.12
20	2.10	3.30	(a)	1.80	1.62	1.00	.72	.72	2.62	.70	.80	1.08
21	2.05	4.80	(a)	1.77	1.58	.95	.72	.72	1.32	.72	.79	1.05
22	2.02	6.85	(a)	1.72	1.55	.92	.72	.70	1.22	.70	.78	1.00
23	2.00	5.45	(a)	1.68	1.52	.90	.70	.70	1.15	.73	.78	1.10
24	1.90	5.35	(a)	1.65	1.46	.90	.70	.68	1.00	.73	.74	1.12
25	2.00	5.15	(a)	1.62	1.38	.95	.71	.62	1.00	.72	.74	1.20
26	2.05	.....	(a)	1.65	1.30	1.00	.72	.62	.98	.72	.72	1.30
27	2.00	6.15	(a)	1.62	1.28	.95	.75	b1.00	1.10	.72	.70	1.10
28	2.00	.....	(a)	1.60	1.25	.95	.75	1.62	1.08	.72	.65	1.15
29	1.95	.....	(a)	1.53	1.22	1.00	.74	1.35	1.00	.71	.70	1.20
30	1.90	.....	2.90	1.48	1.48	.97	.72	1.02	.98	.70	.75	1.21
31	1.85	.....	2.72	.....	1.46	.....	.72	.92	.....	.85	.....	1.00

a No observations. b Interpolated.

JAMES RIVER AT BUCHANAN, VIRGINIA.

This river rises in the Allegheny Mountains, on the western border of Virginia, and flows in an easterly direction across the State into Chesapeake Bay. The upper part of its drainage area is mountainous and largely covered with forests, while in the eastern part of the State the river flows through a flat and cultivated area. Measurements of flow are made at Buchanan, in Botetourt County, and at Cartersville, 50 miles above Richmond. The station at Buchanan was established by C. C. Babb and D. C. Humphreys, August 18, 1895. It is about 20 miles above the mouth of North River and one-half mile above the mouth of Purgatory Creek, as shown on the Natural Bridge topographic atlas sheet. The area as far as this point is mapped on the Natural Bridge, Staunton, Monterey, Lewisburg, Dublin, Christiansburg, and Roanoke sheets. The United States Weather Bureau had maintained a gage here for about two years before measurements were made by the Geological Survey. The wire gage is suspended from the steel highway bridge which crosses the river on two spans. On April 3, 1897, the zero of this gage was lowered 2 feet to avoid negative readings. The gage is referred to a scale divided into feet and tenths, and to two bench marks. First, the top of the upper end of the third floor beam from left bank is 30.00 feet above the zero of the gage. Second, the top of a stone post under the southwest corner of the porch of the Chesapeake and Ohio Railroad passenger station is 24.68 feet above zero of gage. A third bench mark is on a permanent ledge of rock on the left bank about 500 feet above the bridge, and at an elevation of 17.48 feet above the zero of the gage. The initial point of soundings is on the left bank, upper side of the bridge, marked with the end pin of the truss. The channel is straight, the flow fairly swift, and without obstructions. The bed is rocky; banks high and not subject to overflow. The observer is U. H. Hyde, a telegraph operator for the Chesapeake and Ohio Railroad, at Buchanan, Virginia. The results of measurement may be found as follows: 1895–96, Eighteenth Annual Report, Part IV, page 41; 1897, Nineteenth Annual Report, Part IV, page 172; 1898, Twentieth Annual Report, Part IV, page 136. During 1899 three measurements of discharge were made by D. C. Humphreys; the first on March 30, at a gage height of 5.54 feet, gave a discharge 6,804 second-feet; the second on July 6, at a gage height of 2.06 feet, gave a discharge 558 second-feet, and the third on August 11, at a gage height of 1.80 feet, gave a discharge of 364 second-feet.

Daily gage height, in feet, of James River at Buchanan, Virginia, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.45	3.10	7.45	4.75	3.80	3.60	3.00	1.90	1.90	1.90	1.80	1.80
2	3.55	3.00	6.55	4.40	3.80	3.70	2.10	1.90	1.90	1.90	1.90	1.80
3	3.40	3.00	6.40	4.30	3.80	3.60	2.10	1.80	1.90	1.90	2.10	1.80
4	3.40	3.40	11.20	4.20	3.80	3.60	2.00	1.80	2.00	1.90	2.30	1.80
5	3.95	4.90	19.05	4.10	3.70	3.60	2.00	1.80	2.10	1.90	2.20	1.80
6	5.95	6.80	13.55	4.10	3.70	3.50	2.05	1.80	2.00	1.80	2.20	1.80
7	10.25	8.40	8.15	4.00	4.05	3.40	2.12	1.80	1.90	1.80	2.10	1.80
8	7.70	7.30	6.70	5.00	5.85	3.30	2.35	1.90	1.80	1.80	2.10	1.80
9	5.95	6.30	5.90	5.75	7.70	3.30	2.35	1.90	2.00	1.80	2.10	1.80
10	5.20	4.50	5.55	5.40	6.65	3.30	2.15	1.90	2.10	1.80	2.00	1.80
11	4.60	4.05	5.35	5.00	5.85	3.30	2.00	1.90	2.20	1.80	2.00	1.80
12	4.20	4.00	5.15	4.85	5.65	3.30	2.00	1.90	2.10	1.80	1.90	2.30
13	4.00	4.00	4.95	4.70	5.60	4.45	2.00	1.90	2.10	1.80	1.90	3.50
14	3.85	3.95	4.65	4.60	6.26	4.50	2.00	2.00	2.00	1.80	1.90	3.05
15	4.15	3.50	4.75	4.45	5.70	4.25	1.90	2.60	2.00	1.80	1.90	2.95
16	4.30	3.60	5.55	4.45	5.20	3.95	1.90	2.45	1.90	1.80	1.90	2.60
17	4.20	3.75	5.30	4.30	4.85	3.70	1.90	2.20	1.90	1.80	1.80	2.45
18	4.20	4.15	5.05	4.05	4.65	3.55	1.90	2.00	1.80	1.80	1.80	2.30
19	4.05	4.85	7.15	4.00	4.50	3.40	1.90	1.90	2.45	1.80	1.80	2.20
20	3.75	5.70	7.80	3.90	4.35	3.30	1.90	1.90	3.60	1.80	1.80	2.20
21	3.60	8.20	6.35	3.90	4.05	3.20	1.90	1.80	3.40	1.70	1.80	2.10
22	3.50	10.20	5.65	3.80	4.00	3.10	1.80	1.80	2.65	1.70	1.80	2.10
23	3.50	9.35	5.20	3.80	3.90	3.10	1.80	1.80	2.35	1.70	1.80	2.10
24	3.40	7.35	4.80	3.70	3.90	3.00	1.80	1.80	2.20	1.70	1.80	2.10
25	3.40	6.15	4.55	3.70	3.90	3.15	1.80	1.80	2.10	1.70	1.80	2.10
26	3.60	5.40	4.25	3.85	3.80	3.10	1.80	1.80	2.10	1.70	1.80	2.25
27	3.50	8.90	4.10	4.20	3.60	3.65	1.90	1.90	2.00	1.70	1.80	2.30
28	3.40	9.65	4.00	4.00	3.60	3.30	1.90	1.80	2.00	1.70	1.80	2.20
29	3.30	.....	4.80	4.00	3.50	3.20	2.00	2.00	2.00	1.70	1.80	2.20
30	3.20	.....	5.55	3.90	3.60	3.10	2.00	1.90	1.90	1.70	1.80	2.20
31	3.10	.....	5.75	.....	3.60	.....	1.90	1.90	.....	1.70	.....	2.20

JAMES RIVER AT CARTERSVILLE, VIRGINIA.

Observations of the height of James River are made by the Weather Bureau at Lynchburg, Virginia, 48 miles below Buchanan and about 100 miles above Cartersville. The drainage area is given as 3,700 square miles. The gage is on the first pier of the Amherst bridge, at the foot of Ninth street, on the side facing Lynchburg, about 100 feet from the shore. The elevation is 494.7 feet above mean sea level. The highest water was about 27 feet on September 30, 1870, and the lowest —0.3 foot on September 12–15, 1895.

Gages were established on James River in 1893 by Mr. F. B. Isaacs, engineer for water power of the Chesapeake and Ohio Railway Company, at Ninemile Locks, Columbia, Scottsville, Lynchburg, Balcony Falls, Buchanan, Eagle Mountain, and Clifton Forge. Records of heights of water at these points were made twice daily from 1893 to 1897, and freshet reports were obtained for these years. The gages were not referred to any fixed datum, but the zero of each gage was set at what was considered ordinary low water in the river. During the latter part of 1899 records have been resumed, excepting at Scottsville, Balcony Falls, and Eagle Mountain, where the gages have been abandoned.

At Bosher's dam, 9 miles above Richmond, is a gage where the height of water is recorded twice daily, showing the supposed head on the crest of dam. This crest, however, is so irregular that the coefficient of discharge has not been ascertained. Another complication exists in the fact that water is deflected into a canal, the quantity not being known.

Observations are maintained by the Weather Bureau at Richmond, Virginia, the gage being at the foot of Virginia street, near Fourteenth, immediately east of the Richmond and Danville Railroad bridge. It is a standard brass Weather Bureau gage embedded in the cement buttress. The elevation of the zero is 2.8 feet.

A gaging station was established January 1, 1899, by Prof. D. C. Humphreys, and is located at the highway bridge crossing the James at Cartersville, on half mile from railroad station and 50 miles above Richmond, Virginia. The drainage area is mapped on the following atlas sheets: Goochland, Farmville, Palmyra, Gordonsville, Harrisonburg, Buckingham, Lexington, Lynchburg, Appomatox, Natural Bridge, Lewisburg, Christiansburg, Roanoke, Staunton, Monterey, and Dublin. The wire gage is attached to a horizontal gage rod fastened to the bridge and is referred to a bench mark, the top of the lower end of the fourth floor beam from the right bank, which is 32.04 feet above the zero of the gage. The gage was verified June 23, 1899. The channel is straight for one-third of a mile above and 1 mile below the station, the current fairly swift, and the bottom somewhat sandy and shifting. The banks are high and not subject to overflow except in extreme high water. The observer is Julien I. Palmore, clerk in a store at Cartersville, Virginia. The following measurements were made by Prof. D. C. Humphreys and F. H. Anschutz. Prior to 1899 two measurements were made, which have not previously been published:

September 8, 1897, gage height, 0.42 foot; discharge, 603 second-feet.
July 16, 1898, gage height, 1.04 feet; discharge, 1,323 second-feet.
January 3, 1899, gage height, 3.82 feet; discharge, 7,156 second-feet.
June 23, 1899, gage height, 1.46 feet; discharge, 2,686 second-feet.

Daily gage height, in feet, of James River at Cartersville, Virginia, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.40	3.30	13.90	6.05	3.00	2.30	1.53	1.30	1.40	1.30	4.97	1.20
2	4.40	3.25	10.35	5.62	2.85	2.20	1.35	1.10	1.32	1.15	4.15	1.20
3	3.70	3.20	8.80	5.15	2.80	2.70	1.25	1.00	2.90	1.10	3.60	1.20
4	4.00	4.30	9.40	4.65	3.05	2.40	1.12	.90	1.44	1.10	5.30	1.20
5	4.00	5.65	20.25	4.60	2.80	2.27	1.22	.85	1.35	1.10	3.30	1.20
6	8.20	7.50	24.70	4.25	2.80	2.10	1.25	2.30	1.15	1.05	2.80	1.20
7	19.50	8.80	19.25	4.15	3.65	2.05	1.30	2.00	1.15	1.00	2.50	1.20
8	15.40	10.50	13.17	9.55	4.50	1.97	1.47	1.45	1.30	1.80	2.20	1.15
9	11.74	8.75	10.40	8.50	5.00	1.75	1.20	1.35	1.60	2.00	1.95	1.10
10	9.00	6.40	10.90	8.15	6.20	1.80	1.15	1.10	1.44	2.05	1.85	1.00
11	7.05	5.10	8.60	7.12	6.50	2.00	1.06	1.00	1.27	1.50	1.60	1.00
12	5.98	5.10	7.30	6.15	7.30	2.30	1.24	1.26	1.20	1.40	1.50	1.10
13	5.40	5.10	7.10	4.90	5.05	3.10	1.09	1.19	1.30	1.30	1.45	3.15
14	5.17	5.10	6.90	4.70	5.65	3.45	1.02	1.09	1.31	1.20	1.75	2.80
15	5.17	6.00	8.12	4.50	5.15	3.40	1.00	1.10	1.13	1.10	1.50	3.10
16	4.70	7.75	10.65	4.15	5.15	3.47	1.07	2.64	1.05	1.10	1.30	2.90
17	5.47	14.00	8.30	4.07	4.45	3.00	1.00	2.12	1.00	1.00	1.30	2.80
18	5.15	9.75	8.05	3.95	3.90	2.10	1.04	1.40	.92	1.20	1.25	2.40
19	4.73	10.55	17.33	3.75	3.65	2.00	1.15	1.30	.85	1.10	1.25	1.80
20	4.50	10.55	18.32	3.60	3.40	1.78	1.05	1.15	3.40	1.00	1.25	1.80
21	4.20	14.00	12.83	3.55	3.17	1.70	.88	.97	5.40	.98	1.25	1.60
22	4.05	16.10	8.80	3.47	2.86	1.50	.82	.80	3.40	.97	1.25	1.50
23	3.85	16.30	8.00	3.32	2.80	1.48	.80	.80	2.65	.98	1.25	1.45
24	3.75	13.75	7.60	3.17	2.70	1.40	.77	.82	2.10	1.00	1.25	1.60
25	4.30	11.00	6.65	3.08	2.50	1.40	.70	.76	1.30	1.00	1.25	1.80
26	4.10	8.65	6.15	3.05	2.45	1.70	.80	.66	3.50	.98	1.25	2.00
27	3.80	10.90	5.85	3.20	2.45	2.10	2.23	7.00	2.35	.97	1.20	2.10
28	3.75	12.30	5.25	3.25	2.15	1.60	2.30	6.45	1.70	.97	1.20	2.00
29	3.55	.....	6.35	3.30	2.05	1.40	1.53	3.50	1.40	.97	1.20	1.80
30	3.50	.....	6.15	3.10	2.20	1.80	1.40	2.70	1.30	.97	1.20	1.75
31	3.42	.....	6.55	.....	2.25	.....	1.70	1.84	.....	.97	.....	1.65

NOTE.—Data concerning other rivers are given in succeeding papers of this series, beginning on page 107 of Water-Supply Paper No 36. By the law approved June 11, 1896 (Stat. L., vol. 29, p. 453), the reports of this series are limited to 100 pages each. It is therefore necessary to arbitrarily subdivide this report on operations at river stations.

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1895.

Sixteenth Annual Report of the United States Geological Survey, 1894–95, Part II, Papers of an economic character, 1895; octavo, 598 pp.

Contains a paper on the public lands and their water supply, by F. H. Newell, illustrated by a large map showing the relative extent and location of the vacant public lands; also a report on the water resources of a portion of the Great Plains, by Robert Hay.

A geological reconnaissance of northwestern Wyoming, by George H. Eldridge 1894; octavo, 72 pp. Bulletin No. 119 of the United States Geological Survey, price, 10 cents.

Contains a description of the geologic structure of portions of the Bighorn Range and Bighorn Basin, especially with reference to the coal fields, and remarks upon the water supply and agricultural possibilities.

Report of progress of the division of hydrography for the calendar years 1893 and 1894, by F. H. Newell, 1895; octavo, 176 pp. Bulletin No. 131 of the United States Geological Survey; price, 15 cents.

Contains results of stream measurements at various points, mainly within the arid region, and records of wells in a number of counties in western Nebraska, western Kansas, and eastern Colorado.

1896.

Seventeenth Annual Report of the United States Geological Survey, 1895–96, Part II, Economic geology and hydrography, 1896; octavo, 864 pp.

Contains papers on "The underground water of the Arkansas Valley in eastern Colorado," by G. K. Gilbert; "The water resources of Illinois," by Frank Leverett, and "Preliminary report on the artesian waters of a portion of the Dakotas," by N. H. Darton.

Artesian-well prospects in the Atlantic Coastal Plain region, by N. H. Darton, 1896; octavo, 230 pp., 19 plates. Bulletin No. 138 of the United States Geological Survey; price, 20 cents.

Gives a description of the geologic conditions of the coastal region from Long Island, N. Y., to Georgia, and contains data relating to many of the deep wells.

Report of progress of the division of hydrography for the calendar year 1895, by F. H. Newell, hydrographer in charge, 1896; octavo, 356 pp. Bulletin No. 140 of the United States Geological Survey; price, 25 cents.

Contains a description of the instruments and methods employed in measuring streams and the results of hydrographic investigations in various parts of the United States.

1897.

Eighteenth Annual Report of the United States Geological Survey, 1896–97, Part IV, Hydrography, 1897; octavo, 756 pp.

Contains a "Report of progress of stream measurements for the calendar year 1896," by Arthur P. Davis; "The water resources of Indiana and Ohio," by Frank Leverett; "New developments in well boring and irrigation in South Dakota," by N. H. Darton, and "Reservoirs for irrigation," by J. D. Schuyler.

1899.

Nineteenth Annual Report of the United States Geological Survey, 1897–98, Part IV, Hydrography, 1899; octavo, 814 pp.

Contains a "Report of progress of stream measurements for the calendar year 1898," by F. H. Newell and others; "The rock waters of Ohio," by Edward Orton, and "A preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian," by N. H. Darton.

1900.

Twentieth Annual Report of the United States Geological Survey, 1898–99, Part IV, Hydrography, 1900; octavo, 660 pp.

Contains a "Report of progress of stream measurements for the calendar year 1899," by F. H. Newell, and "Hydrography of Nicaragua," by A. P. Davis.

WATER-SUPPLY AND IRRIGATION PAPERS, 1896–1900.

This series of papers is designed to present in pamphlet form the results of stream measurements and of special investigations. A list of these, with other information, is given on the outside (or fourth) page of this cover.

Survey bulletins can be obtained only by prepayment of cost, as noted above. Money should be transmitted by postal money order or express order, made payable to the Director of the United States Geological Survey. Postage stamps, checks, and drafts can not be accepted. Correspondence relating to the publications of the Survey should be addressed to **The Director, United States Geological Survey, Washington, D. C.**

WATER-SUPPLY AND IRRIGATION PAPERS.

1. Pumping water for irrigation, by Herbert M. Wilson, 1896.
2. Irrigation near Phœnix, Arizona, by Arthur P. Davis, 1897.
3. Sewage irrigation, by George W. Rafter, 1897.
4. A reconnoissance in southeastern Washington, by Israel C. Russell, 1897.
5. Irrigation practice on the Great Plains, by E. B. Cowgill, 1897.
6. Underground waters of southwestern Kansas, by Erasmus Haworth, 1897.
7. Seepage waters of northern Utah, by Samuel Fortier, 1897.
8. Windmills for irrigation, by E. C. Murphy, 1897.
9. Irrigation near Greeley, Colorado, by David Boyd, 1897.
10. Irrigation in Mesilla Valley, New Mexico, by F. C. Barker, 1898.
11. River heights for 1896, by Arthur P. Davis, 1897.
12. Water resources of southeastern Nebraska, by Nelson Horatio Darton, 1898.
13. Irrigation systems in Texas, by William Ferguson Hutson, 1898.
14. New tests of pumps and water lifts used in irrigation, by O. P. Hood, 1898.
15. Operations at river stations, 1897, Part I, 1898.
16. Operations at river stations, 1897, Part II, 1898.
17. Irrigation near Bakersfield, California, by C. E. Grunsky, 1898.
18. Irrigation near Fresno, California, by C. E. Grunsky, 1898.
19. Irrigation near Merced, California, by C. E. Grunsky, 1899.
20. Experiments with windmills, by Thomas O. Perry, 1899.
21. Wells of northern Indiana, by Frank Leverett, 1899.
22. Sewage irrigation, Part II, by George W. Rafter, 1899.
23. Water-right problems of the Bighorn Mountains, by Elwood Mead, 1899.
24. Water resources of the State of New York, Part I, by George W. Rafter, 1899.
25. Water resources of the State of New York, Part II, by George W. Rafter, 1899.
26. Wells of southern Indiana (continuation of No. 21), by Frank Leverett, 1899.
27. Operations at river stations, 1898, Part I, 1899.
28. Operations at river stations, 1898, Part II, 1899.
29. Wells and windmills in Nebraska, by Erwin Hinckley Barbour, 1899.
30. Water resources of the Lower Peninsula of Michigan, by Alfred C. Lane, 1899.
31. Lower Michigan mineral waters, by Alfred C. Lane, 1899.
32. Water resources of Puerto Rico, by H. M. Wilson, 1900.
33. Storage of water on Gila River, Arizona, by J. B. Lippincott, 1900.
34. Underground waters of a portion of southeastern S. Dak., by J. E. Todd, 1900.
35. Operations at river stations, 1899, Part I, 1900.
36. Operations at river stations, 1899, Part II, 1900.
37. Operations at river stations, 1899, Part III, 1900.

In addition to the above, there are in various stages of preparation other papers relating to the measurement of streams, the storage of water, the amount available from underground sources, the efficiency of windmills, the cost of pumping, and other details relating to the methods of utilizing the water resources of the country. Provision has been made for printing these by the following clause in the sundry civil act making appropriations for the year 1896–97:

Provided, That hereafter the reports of the Geological Survey in relation to the gaging of streams and to the methods of utilizing the water resources may be printed in octavo form, not to exceed 100 pages in length and 5,000 copies in number; 1,000 copies of which shall be for the official use of the Geological Survey, 1,500 copies shall be delivered to the Senate, and 2,500 copies shall be delivered to the House of Representatives, for distribution. [Approved June 11, 1896; Stat. L., vol. 29, p. 453.]

The maximum number of copies available for the use of the Geological Survey is 1,000. This number falls far short of the demand, so that it is impossible to supply all requests. Attempts are made to send these pamphlets to persons who have rendered assistance in their preparation through replies to schedules or who have furnished data. Requests specifying a certain paper and stating a reason for asking for it are granted whenever practicable, but it is impossible to comply with general and indiscriminate demands, such as to have all of the series sent.

Application for these papers should be made either to Members of Congress or to

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C.

56TH CONGRESS, 1st Session. } HOUSE OF REPRESENTATIVES. { DOCUMENT No. 722.

DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 36

OPERATIONS AT RIVER STATIONS, 1899.—PART II

WASHINGTON
GOVERNMENT PRINTING OFFICE
1900

UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

OPERATIONS AT RIVER STATIONS, 1899

A REPORT OF THE

DIVISION OF HYDROGRAPHY

OF THE

UNITED STATES GEOLOGICAL SURVEY

PART II

WASHINGTON
GOVERNMENT PRINTING OFFICE
1900

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OPERATIONS AT RIVER STATIONS, 1899.

PART II.

MEASUREMENTS AT RIVER STATIONS.[1]

ROANOKE RIVER AT ROANOKE, VIRGINIA.

This river rises in Montgomery County, Virginia. Its headwaters are near those of New River on the west. This stream lower down is known as Staunton River, and joins the Dan at Danville to form the main lower Roanoke River. There are a number of fine water powers along its length, described more fully in the Nineteenth Annual Report, Part IV, page 176. The drainage area is mapped on the Roanoke and Christiansburg sheets. The gaging station was established by Prof. D. C. Humphreys July 10, 1896, and is located on the edge of the town of Roanoke, Virginia, on the Walnut street car line. The gage is of wire, with the rod fastened to the floor of the bridge. The top of the lower end of the first floor beam is 21.99 feet above gage datum. The length of gage wire is 24.39 feet. The right bank is above high water, but the left is liable to overflow in extreme high stages. The channel is nearly straight and the current good. The results of discharge measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 42; 1897–98, Twentieth Annual Report, Part IV, page 140. The following measurements were made during 1899 by D. C. Humphreys: The first, on May 29, at a gage height of 2.51 feet, gave a discharge of 1,123 second-feet; the second one, on June 27, at a gage height of 1.32 feet, gave a discharge of 290 second-feet; the third, on August 7, at a gage height of 0.88 foot, gave a discharge of 135 second-feet.

[1] Continued from Water-Supply and Irrigation Paper No. 35.

Daily gage height, in feet, of Roanoke River at Roanoke, Virginia, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.80	2.25	3.20	2.00	1.43	1.15	1.00	0.90	0.75	0.65	1.20	0.80
2	1.80	2.20	2.95	1.88	1.40	1.30	1.05	.80	.85	.65	1.17	.80
3	1.75	2.05	2.85	1.79	1.39	1.18	1.08	.80	1.00	.65	1.25	.75
4	2.00	3.10	6.15	1.75	1.35	1.08	1.00	.70	.85	.65	1.30	.75
5	1.90	3.50	8.15	1.73	1.32	1.00	1.00	.70	.75	.65	1.10	.75
6	3.13	3.75	4.70	1.67	1.32	.98	1.00	.80	.75	.63	1.05	.75
7	5.85	4.08	3.68	1.62	1.41	.97	1.05	.90	.70	.60	1.00	.77
8	3.55	3.90	3.10	2.10	1.80	.95	.98	.85	.65	.85	.95	.80
9	2.90	3.85	3.00	1.90	2.08	.90	.93	.85	.70	.90	.90	.78
10	2.40	3.60	2.80	1.80	1.85	.95	.90	.85	.65	.80	.85	.75
11	2.50	3.50	2.70	1.75	1.78	1.00	.85	.75	.60	.85	.83	.75
12	2.40	2.45	a3.10	1.70	1.70	1.75	.82	.75	.57	.80	.80	1.50
13	2.30	2.25	a3.50	1.66	1.82	2.25	.80	.95	.70	.75	.80	1.55
14	2.80	a2.22	3.90	1.63	1.85	1.90	.80	1.00	.65	.70	.80	1.30
15	2.70	2.20	4.75	1.60	1.75	1.65	.95	1.00	.65	.70	.80	1.15
16	2.55	2.20	4.25	1.55	1.66	1.45	.83	.95	.65	.80	.78	1.05
17	2.45	3.55	3.70	1.52	1.57	1.30	.75	.90	.65	.77	.78	.95
18	2.30	3.25	3.45	1.47	1.46	1.18	1.05	.80	.65	.75	.75	.90
19	2.20	3.50	7.10	1.45	1.40	1.15	.90	.75	1.46	.73	.75	.90
20	2.15	3.95	4.90	1.40	1.31	1.10	.85	.72	2.05	.70	.73	.90
21	2.10	4.50	3.90	1.40	1.28	1.08	.82	.70	1.25	.70	.73	.88
22	2.07	4.40	3.55	1.37	1.25	1.05	.78	.67	1.00	.68	.70	.85
23	2.05	3.75	3.35	1.36	1.35	1.00	.80	.65	.85	.68	.75	.80
24	2.50	3.25	3.15	1.34	1.27	1.00	.85	.68	.80	.68	.75	1.10
25	2.25	2.90	3.00	1.38	1.20	1.10	.90	.60	.80	.68	.75	1.05
26	2.15	2.70	2.35	1.75	1.16	2.15	.85	.65	.75	.66	.73	.95
27	2.10	5.00	2.40	1.70	1.15	1.45	1.15	.75	.85	.65	.73	.90
28	2.05	3.65	2.45	1.60	1.13	1.15	1.00	.85	.75	.65	.75	1.25
29	a2.10	.....	2.30	1.50	1.10	1.05	.85	1.00	.70	.65	1.00	1.30
30	a2.20	.....	2.15	1.48	1.20	1.00	.82	.85	.65	.73	.85	1.45
31	2.25	.....	2.10	.....	1.13	.....	1.05	.80	.....	.80	.....	1.60

a Interpolated.

Main Roanoke River is formed by the junction of Dan and Staunton rivers at Clarksville, Virginia, and flows southerly, entering Albemarle Sound. The United States Weather Bureau has a station on Dan River at Danville, Virginia, 55 miles above the mouth of Staunton River. The gage is of timber, and is attached to the first pier of the iron bridge between North and South Danville. The highest water was 13.0, on September 13, 1893; lowest, 0.02, on January 26, 1894. The danger line is at 8 feet. The drainage area above the station is 1,900 square miles, according to the United States Weather Bureau.

A second gaging station is maintained by the United States Weather Bureau on Roanoke River at Clarksville, Virginia, 65 miles above Weldon, North Carolina. The river gage is on the south side of the river, attached to a tree leaning over the water. The highest recorded water was 13.5 feet, on September 14, 1893, and the lowest—0.2 foot, on July 19, 1894. It is reported that on November 27, 1877, a height of 27 feet was reached. The danger line is at 12 feet. The drainage area above the station is 6,900 square miles, according to the United States Weather Bureau.

The third station maintained by the Weather Bureau on this river is erected at Weldon, North Carolina, 30 miles above Neal and 90 miles above Albemarle Sound. The river gage is located below the Atlantic Coast Line Railroad bridge, on the south side of the river. The gage is of white pine and is made of three sections, the lowest section, 4 feet to 17 feet, is of detached pieces fastened to trees which lean over the river; the second section, 17 feet to 47 feet, is attached to the fore bay of the Roanoke mills; above 47 feet the gage is painted

on the mill building. The zero of the gage is 4 feet below a large rock, known as "Big Cuba." It is 31 feet below the railroad crossing. The highest recorded water is 46.8 feet, on November 26, 1877; the lowest, —0.3, on August 21, 1893. The danger line is at 27 feet. The drainage area above Weldon, according to the United States Weather Bureau, is 8,180 square miles.

ROANOKE RIVER AT NEAL, NORTH CAROLINA.

This station, described in the Eighteenth Annual Report, Part IV, page 47, was established July 27, 1896, and is on the Norfolk and Carolina Railroad bridge, near Neal, North Carolina. The bench marks for the gage rod are described in Water-Supply Paper No. 15, page 28. The length of the gage wire is 44.66 feet. The section is a fairly good one, the course of the river being straight for some distance above and below the station and the bottom smooth. Being muddy, however, the bed is apt to cut out in seasons of high water and both banks are subject to overflow. The observer is the bridge watchman, Mr. W. M. Adams, of Neal, North Carolina. Records of measurement may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 48; 1897, Nineteenth Annual Report, Part IV, page 181; 1898, Twentieth Annual Report, Part IV, page 142. The measurements made by E. W. Myers during 1899 are as follows:

February 5, gage height, 20.80 feet; discharge, 23,998 second-feet.
May 25, gage height, 6.41 feet; discharge, 6,045 second-feet.
June 7, gage height, 6.45 feet; discharge, 6,110 second-feet.
October 12, gage height, 8.60 feet; discharge, 7,973 second-feet.
November 28, gage height, 4.13 feet; discharge, 4,439 second-feet.

Daily gage height, in feet, of Roanoke River at Neal, North Carolina, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	7.40	9.10	22.80	20.60	10.50	8.10	8.40	7.30	11.00	3.60	4.30	4.00
2	7.60	10.20	23.40	19.10	9.50	10.30	7.20	6.50	8.20	3.00	10.50	4.20
3	10.50	10.70	22.80	17.40	9.00	12.20	5.70	5.90	5.70	2.70	12.30	4.30
4	14.20	11.00	21.80	16.00	9.10	12.60	4.70	5.10	4.10	2.50	12.00	4.20
5	13.10	20.75	22.70	15.20	9.00	10.50	4.20	3.80	3.90	2.30	13.40	4.10
6	11.35	22.35	24.00	14.90	8.80	8.30	4.20	3.50	5.70	2.80	14.15	3.95
7	10.80	23.95	25.25	15.00	8.70	6.50	4.60	3.60	5.00	5.30	12.10	3.80
8	17.25	25.55	26.08	17.70	8.60	5.40	7.10	4.20	4.00	6.90	9.50	3.50
9	23.25	26.80	26.10	21.40	8.70	4.90	11.10	5.60	3.10	7.80	7.60	3.30
10	25.50	27.05	25.10	23.00	8.90	4.60	11.20	6.70	2.70	9.10	6.30	3.20
11	27.75	26.40	23.20	23.60	10.80	5.00	9.80	6.20	3.70	9.90	5.50	3.10
12	26.80	24.50	21.20	22.30	11.30	8.10	7.50	5.00	5.80	8.70	5.10	3.20
13	24.55	21.30	19.20	20.20	13.00	17.80	5.50	5.40	6.00	6.90	4.60	3.50
14	22.25	17.50	17.60	18.30	12.60	21.50	4.20	7.30	5.50	5.50	4.30	7.00
15	21.80	14.30	17.70	16.80	11.90	22.40	3.50	5.40	4.30	4.50	4.10	11.50
16	21.00	12.50	22.80	15.40	11.40	22.40	3.20	4.50	3.40	3.90	4.00	11.50
17	19.05	12.90	28.80	14.30	10.40	21.00	3.10	6.50	2.90	3.60	3.90	9.20
18	18.00	19.50	25.70	13.40	9.20	18.10	3.30	10.90	2.40	3.45	3.80	7.20
19	16.90	19.60	26.80	12.60	8.10	15.20	3.40	9.20	2.10	3.30	3.70	6.00
20	15.80	24.70	26.10	11.90	7.50	12.40	4.20	7.20	2.00	3.25	3.60	5.10
21	14.40	26.80	26.10	11.40	7.10	10.20	4.50	5.40	2.00	3.00	3.50	4.70
22	13.20	27.25	27.80	10.50	6.90	8.60	4.80	4.80	11.25	3.20	3.40	4.40
23	12.20	26.90	30.00	10.00	6.60	7.30	3.90	3.80	14.00	2.90	3.35	4.30
24	11.30	26.20	29.35	9.70	6.30	6.30	3.80	2.80	10.60	2.80	3.35	4.45
25	10.80	25.20	27.40	9.40	6.40	5.20	4.70	2.40	7.55	2.70	3.60	6.40
26	10.30	23.60	25.50	9.10	6.90	4.80	4.80	2.10	5.40	2.60	3.80	8.40
27	10.10	22.00	22.80	9.40	7.00	4.40	7.20	1.80	4.70	2.60	4.00	8.60
28	9.90	21.80	20.70	11.80	6.40	4.30	7.30	1.60	4.90	2.60	4.10	8.10
29	8.70	.....	19.60	12.30	5.90	6.30	11.80	1.70	5.10	2.70	3.80	6.80
30	8.20	.....	20.10	11.60	5.60	6.70	11.90	13.70	4.60	2.70	3.70	5.60
31	8.60	.....	21.00	.....	5.90	.....	9.50	12.90	.....	3.00	.....	3.50

TAR RIVER AT TARBORO, NORTH CAROLINA.

Tar River rises in the north-central part of North Carolina and flows in a southeasterly direction into Pamlico River. It crosses the fall line at Rocky Mount, North Carolina, where is located the principal power on the river. The fall below this point is from 1 to 1½ feet per mile. The fall above this point is about 2 feet per mile, concentrated at a number of points where small powers can be developed. The drainage basin is largely covered with forest. The stream is subject to violent freshets and periods of very low flow. The gaging station, as described in the Eighteenth Annual Report, Part IV, page 50, is on the Atlantic Coast Line bridge, crossing the river at Tarboro, North Carolina, and was established by E. W. Myers on July 24, 1896. The length of the wire gage is 38.30 feet. The channel is straight, the current moderately swift, the banks low and flooded in high water. The bed is sandy and fairly constant. Sand bars slightly obstruct the flow of the river. The observer is R. H. Williams, who reads the gage once a day. Measurements of discharge are made at the highway bridge which crosses the stream about 200 yards above, this point furnishing a better station. Records of flow may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 52; 1897, Nineteenth Annual Report, Part IV, page 184; 1898, Twentieth Annual Report, Part IV, page 143. The following measurements were made by E. W. Myers during 1899:

February 5, gage height, 9.10 feet; discharge, 5,165 second-feet.
May 24, gage height, 2.60 feet; discharge, 1,125 second-feet.
June 7, gage height, 2.00 feet; discharge, 798 second-feet.
October 16, gage height, 2.95 feet; discharge, 1,150 second-feet.
November 28, gage height, 2.20 feet; discharge, 875 second-feet.

Daily gage height, in feet, of Tar River at Tarboro, North Carolina, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.20	6.30	15.00	8.60	4.60	2.40	1.00	10.00	0.60	1.70	4.30	3.70
2	3.10	7.20	14.80	7.80	4.10	3.50	1.00	10.60	.50	1.30	6.50	2.80
3	3.40	8.30	15.40	7.20	3.90	3.00	.95	9.60	.40	1.40	9.30	2.70
4	3.70	8.50	16.70	6.30	4.00	2.90	1.00	7.70	.30	.90	9.70	3.00
5	3.50	8.90	16.50	7.00	3.90	3.00	.95	5.50	.60	.80	6.50	3.20
6	3.30	12.50	17.80	8.00	3 80	2.50	.70	4.50	.50	1.40	5.70	2.80
7	3.40	15.70	18.30	8.90	3.60	2.00	3.20	4.00	.40	2.20	5.20	2.60
8	3.50	18.60	18.60	11.70	3.50	1.60	2.50	3.70	.50	7.00	4.60	2.50
9	3.40	21.90	18.40	14.50	3.60	1.50	2.00	4.50	.70	8.70	4.20	2.30
10	4.30	24.10	16.40	16.50	3.70	3.00	1.50	4.90	3.00	7.30	3.60	2.30
11	3.40	25.00	13.80	17.80	3.80	2.80	1.60	3.80	1.60	6.80	3.40	2.00
12	3.30	Ice.	11.10	18.30	3.60	2.50	2.50	3.10	3.60	6.00	3.00	2.20
13	3.70	Ice.	9.00	17.00	3.50	5.40	1.60	2.60	5.00	5.20	2.70	2.40
14	4.80	Ice.	8.20	14.40	4.30	7.60	1.40	3.00	3.30	4.30	2.60	3.00
15	6.80	14.75	9.80	10.70	4.00	9.30	1.10	4.10	2.10	3.50	2.40	3.70
16	8.80	11.70	13.80	8.00	4.30	10.60	1.00	3.80	1.60	3.00	2.30	3.50
17	10.30	11.80	16.70	7.00	3.70	9.50	.90	4.30	1.50	2.70	2.40	2.90
18	10.40	14.10	19.00	6.20	3.10	9.80	1.10	5.20	1.10	2.40	2.20	2.60
19	9.10	17.00	20.90	5.80	2.80	8.80	1.40	6.00	1.00	2.20	2.00	2.50
20	8.30	19.00	21.00	5.40	2.60	5.80	3.80	5.40	.80	2.00	1.80	2.40
21	7.00	22.00	19.70	5.50	2.80	3.70	3.20	4.80	.70	.80	2.10	2.30
22	5.90	23.00	17.50	5.30	2.60	3.00	2.80	4.20	.62	1.60	2 00	2.50
23	5.30	23.40	16.30	5.00	2.70	2.40	1.70	3.00	.50	1.50	1.90	2.10
24	4.90	23.10	13.70	4.60	2.70	2.00	1.30	2.80	.60	1.40	1.80	2.90
25	4.50	22.00	10.00	4.30	2.80	1.50	1.50	2.50	1.30	1.80	1.90	5.40
26	4.40	20.50	8.60	4.10	2.70	1.40	2.60	1.80	1.00	1.40	2.00	7.80
27	4.50	18.20	7.80	4.30	2.50	1.50	3.90	1.70	.50	1.30	1.90	8.50
28	4.70	16.30	7.50	5.40	2.30	1.40	6.90	1.50	3.50	1.10	2.20	6.80
29	4.10	.....	7.40	7.50	1.90	1.00	8.20	1.40	3.80	1.30	2.40	5.40
30	4.20	.....	7.90	6.20	2.10	.98	8.50	1.10	2.60	2.50	2.70	5.00
31	4.30	.....	8.50	.....	1.70	.....	9.45	.80	.....	3.20	.....	4.10

NEUSE RIVER AT SELMA, NORTH CAROLINA.

Neuse River rises in the north-central part of North Carolina, and flows in a southeasterly direction, emptying into Pamlico Sound. The stream crosses the fall line at Smithfield, below which point there is no power. The elevation of the river at Smithfield is about 106 feet. At the crossing of the Seaboard Air Line Railroad, some 35 miles above, the elevation is about 175 feet, making the fall in this part of the river about 2 feet per mile. Above this point the fall is much greater. A large part of the area drained by this stream is forest covered. The river is subjected to violent freshets and to periods of low flow. The minimum flow per square mile decreases rapidly as the stream is ascended. A weir measurement of Eno River where the drainage area was about 100 square miles, gave a flow of 3,000,000 gallons per twenty-four hours, or 4.64 second-feet, or at the rate of 0.046 cubic feet per second per square mile. This measurement was made during the severe drought of the summer of 1897. There are a number of localities where power can be developed. The gaging station described in the Eighteenth Annual Report, Part IV, page 52, is located on the Southern Railway bridge, about 3 miles from Selma, North Carolina. It was established by E. W. Myers, July 29, 1896. The bed of the river here is sandy and muddy and is liable to change in high water. The flow is obstructed by one pier of the bridge; the channel is straight, the current moderately swift and confined to one channel. The gage rod was moved February 6, 1899, to the highway bridge, crossing the river about 200 yards below. The zero of the gage rod is 33.7 feet west of the center rod of the truss of the bridge, and on the downstream side. The outer rim of the pulley wheel is 4.75 feet east of the zero of the gage rod, and the distance from the end of the weight to the marker on wire is 35.00 feet. When this station was visited on May 23, 1899, the gage was measured, and this distance was found to be 35.35 feet. When visited in June this length was found to be 35.37 feet; in October 35.48 feet, and at the November visit it was found to be 35.50 feet. This error has been allowed to accumulate, and gage heights on the attached sheet have been adjusted by these measurements. The observer is C. Richardson, engineer at pumping station, Selma, North Carolina. Records of flow may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 53; 1897, Nineteenth Annual Report, Part IV, page 186; 1898, Twentieth Annual Report, Part IV, page 144. The following measurements were made by E. W. Myers during 1899:

February 6, gage height, 15.68 feet; discharge, 7,807 second-feet.
May 23, gage height, 4.28 feet; discharge, 1,262 second-feet.
June 5, gage height, 3.10 feet; discharge, 778 second-feet.
October 12, gage height, 1.79 feet; discharge, 574 second-feet.
November 26, gage height, 1.30 feet; discharge, 356 second-feet.

Daily gage height, in feet, of Neuse River at Selma, North Carolina, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.40	6.50	13.39	4.79	1.84	4.44	1.21	10.68	0.95	1.43	10.50	1.10
2	1.30	5.90	12.99	4.99	1.69	3.54	1.21	9.58	.85	1.23	11.20	1.50
3	1.30	5.60	14.19	4.99	2.69	3.14	1.11	7.98	.75	1.02	11.40	1.60
4	2.00	6.00	15.48	5.78	2.89	3.23	1.11	6.18	.75	.72	11.20	1.40
5	2.50	11.30	18.28	6.28	3.13	3.13	1.21	2.18	.85	.52	4.20	1.20
6	2.00	13.40	17.98	8.48	2.88	2.68	1.31	2.28	.65	.62	3.30	1.20
7	2.10	19.90	17.87	9.77	2.48	1.83	1.40	2.68	.45	3.92	2.70	1.20
8	7.10	20.09	16.47	13.97	3.13	1.83	2.50	3.18	.55	6.82	2.30	1.20
9	6.50	20.98	13.97	16.67	3.42	2.63	3.00	3.67	.65	7.12	2.10	1.20
10	6.40	20.28	10.06	14.76	4.02	5.23	2.60	3.57	.55	7.42	2.10	1.20
11	3.50	18.97	8.16	11.76	4.77	7.03	2.40	3.47	.44	3.92	2.00	1.20
12	3.40	12.37	9.26	7.06	4.47	7.83	1.60	2.57	.84	2.72	1.50	1.40
13	3.20	10.36	9.15	4.95	3.76	9.73	1.40	2.47	.94	2.12	1.40	1.90
14	3.70	9.96	10.35	4.75	5.26	6.27	1.10	3.07	1.04	1.51	2.00	3.80
15	3.90	9.55	11.95	4.55	5.31	3.22	1.00	3.17	.94	1.31	2.00	3.20
16	3.90	6.45	18.05	4.54	4.46	2.62	1.00	2.57	.84	1.11	1.80	2.40
17	3.00	13.55	16.94	4.34	3.26	2.42	1.60	1.67	.74	.71	1.60	1.30
18	6.20	15.54	14.94	4.24	3.05	2.32	4.39	1.77	.64	1.01	1.50	1.20
19	5.20	17.34	18.23	4.03	4.10	2.02	5.59	1.67	.64	1.21	1.50	1.00
20	4.20	18.13	17.73	3.73	5.90	1.82	4.79	1.06	.74	1.31	1.50	1.00
21	3.20	18.73	12.53	3.63	5.35	1.72	2.79	.96	.64	1.31	1.40	1.50
22	2.40	17.02	9.82	3.53	4.80	1.62	2.39	.96	.63	1.31	1.30	1.90
23	2.50	17.32	8.02	3.32	4.40	1.52	1.59	.86	.73	1.31	1.20	3.00
24	2.50	15.32	6.82	3.12	3.74	1.42	1.29	.86	.83	1.11	1.10	3.00
25	2.40	14.21	5.41	3.21	3.44	1.42	3.59	.96	.83	1.01	1.00	2.20
26	3.10	15.51	5.21	3.41	2.84	1.31	6.59	.96	1.43	.80	1.00	1.90
27	3.10	15.20	5.11	4.21	2.44	1.31	10.19	.96	1.67	.70	.90	1.40
28	3.00	14.00	5.60	4.70	2.14	1.31	7.71	.96	2.58	.70	.80	1.20
29	2.80	.....	6.50	5.50	1.94	1.21	5.68	.86	2.87	.80	.70	1.20
30	2.40	.....	6.90	1.95	3.04	1.21	6.58	.96	1.53	.80	.70	1.20
31	2.40	.....	7.60	.....	5.04	.....	8.28	.95	.....	10.70	.....	1.30

HAW RIVER AT MONCURE, NORTH CAROLINA.

This station, established May 6, 1898, by E. W. Myers, is located 1¾ miles north of Moncure, Chatham County, North Carolina, at the bridge of the Seaboard Air Line, which crosses the river here, and about 2 miles from the junction of the river with Deep River to form the Cape Fear. The observer is M. A. Moore, Moncure, North Carolina, who also attends the station on Deep River. The gage is a horizontal rod well painted, divided into feet and tenths, securely nailed to the outer side of the guard rail of the bridge on the upstream side. The 2-foot mark on the rod is over the center of the second floor beam from the south end of the second span from the south end of the bridge. The length of gage was last verified November 26, 1899. The initial point for sounding is a notch cut in the guard rail opposite the south end of the bridge and on the upstream side, the section here being better than that on the downstream side. The channel is straight for some distance above and below the station. The velocity is good and uniformly distributed across the stream. Both banks are rather low and subject to overflow in time of flood. The bed of the stream is of coarse sand and gravel, and is probably not subject to any decided change in high water. The current here is somewhat modified by a fish dam about 150 yards above the bridge. The station is reached by private conveyance from Moncure. When the station was established in May, 1898, the distance from the end of the weight to the pointer on the wire was 43.45 feet. When it was visited in

August, 1898, the wire was measured and this distance was found to be 43.67 feet. In February, 1899, the gage was measured and found to be 43.75 feet. This length remained the same at the subsequent visits during the year, in June, October, and November. The error was not corrected on the gage at each visit, it being considered preferable to change the gage heights after the stretch was found to have become fixed. The gage heights for 1899, as published below, have been corrected. The following measurements were made during 1899 by E. W. Myers:

February 4, gage height, 8.96 feet; discharge, 5,594 second-feet.
May 26, gage height, 2.20 feet; discharge, 751 second-feet.
June 5, gage height, 2.99 feet; discharge, 1,275 second-feet.
October 12, gage height, 1.85 feet; discharge, 756 second-feet.
November 26, gage height, 1.87 feet; discharge, 358 second-feet.

Daily gage height, in feet, of Haw River at Moncure, North Carolina, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.06	4.98	15.70	5.54	2.94	2.62	1.43	4.16	1.07	1.04	10.53	1.28
2	3.68	4.48	9.06	4.68	2.70	2.60	1.31	3.42	.96	1.02	6.87	1.16
3	3.30	4.30	9.98	4.46	2.60	3.94	1.20	2.68	.91	.82	3.96	1.54
4	2.86	8.70	15.66	3.92	2.42	3.56	1.18	2.26	1.04	.82	4.61	1.52
5	2.84	16.40	18.48	3.86	2.38	2.96	7.90	1.48	1.02	.85	3.54	1.48
6	2.48	23.42	14.84	8.84	2.44	2.20	2.24	1.42	1.06	7.65	2.66	1.32
7	12.06	24.66	13.56	4.86	1.96	1.84	2.08	4.85	.96	5.62	2.09	1.30
8	10.32	26.13	9.41	11.12	7.86	1.62	2.22	4.92	.96	7.37	1.64	1.12
9	8.62	26.62	6.68	13.42	6.14	1.40	1.22	4.90	1.00	5.98	1.67	1.06
10	4.98	17.70	5.16	7.06	4.50	1.52	1.04	4.46	2.51	4.13	1.62	1.12
11	3.84	12.34	4.52	5.98	4.42	2.45	1.70	2.02	2.84	2.97	1.57	1.22
12	3.62	6.92	4.34	4.64	4.98	5.18	1.46	1.56	3.40	1.80	1.57	3.12
13	3.94	6.62	4.06	4.12	8.06	4.44	1.38	1.58	1.70	1.62	1.33	1.84
14	5.14	5.84	6.34	3.70	8.62	4.12	1.20	1.20	1.90	1.35	1.31	1.82
15	11.62	5.46	22.07	3.88	5.04	2.94	1.30	1.14	1.24	1.29	1.43	1.68
16	7.96	7.42	23.36	3.62	4.10	2.55	1.23	1.80	1.20	1.34	1.15	1.36
17	6.88	18.92	17.18	3.08	3.86	2.40	1.14	1.52	1.16	1.11	1.08	1.52
18	5.04	18.38	8.62	2.96	2.90	1.72	1.32	1.26	1.12	1.29	1.32	1.48
19	4.44	18.41	14.98	2.88	2.92	1.60	1.34	1.42	1.98	1.24	1.42	1.44
20	3.70	14.72	14.34	2.70	2.86	1.62	1.28	1.06	1.02	1.21	1.44	1.28
21	4.16	11.62	10.98	2.80	2.00	1.54	1.30	1.04	1.07	1.22	1.40	1.32
22	2.90	9.18	7.61	2.64	1.92	1.33	1.36	.92	1.46	1.20	1.38	1.26
23	2.98	8.26	5.44	3.44	2.94	1.59	1.34	.90	1.18	1.07	1.34	1.18
24	3.08	7.28	4.92	2.40	2.96	1.48	1.23	1.08	1.08	.94	1.26	1.54
25	3.16	5.40	4.72	2.42	2.62	1.36	1.28	1.08	2.04	.94	1.28	1.56
26	3.18	6.18	4.62	4.84	2.32	1.30	1.50	1.30	1.38	1.13	1.32	1.52
27	3.15	6.84	4.07	5.08	2.06	1.20	7.14	.92	1.24	1.17	1.98	1.38
28	3.10	13.58	6.34	4.10	1.90	1.38	6.30	1.00	1.06	1.04	2.84	1.32
29	2.50	.....	10.58	3.52	1.84	1.10	3.48	1.06	1.09	1.19	2.90	1.24
30	3.32	.....	7.46	2.98	2.20	1.54	2.02	1.40	.98	1.92	2.56	1.14
31	3.98	.....	6.34	.....	3.16	.....	5.68	1.18	.....	3.46	.....	2.38

DEEP RIVER AT MONCURE, NORTH CAROLINA.

This station, established May 5, 1898, by E. W. Myers, is located about one-fourth of a mile south of Moncure, Chatham County, North Carolina, at the covered wooden bridge of the Seaboard Air Line, which crosses the river here. It is about 2 miles above the junction with the Haw River to form the Cape Fear. The observer is M. A. Moore, of Moncure, North Carolina, a farmer and bridge watchman living about 100 yards from the bridge. The gage is a horizontal rod, well painted, divided into feet and tenths, and securely nailed to the guard rail of the bridge. The zero of the rod is 50 feet south of the

north end of the second span of the bridge from the north. The initial point of sounding is a notch cut in the guard rail opposite the south end of the bridge and on the downstream side. The channel is straight for some distance above and below the station. The banks are low and the bed probably slightly shifting during high water. The velocity is not great, but sufficient for proper measurement, and is well distributed across the stream. When the station was established on May 5, 1898, the distance from the end of the weight to the pointer on the wire was 45.16 feet. At every subsequent trip the gage wire has been measured, and it was discovered that the length was gradually increasing. When the station was visited on August 20, 1898, the length of the wire was found to be 45.27 feet. February, 1899, the length was found to be 45.38 feet; in May, 45.40 feet; in June, 45.45 feet; in October, 45.57 feet, and in November, 45.60 feet. These errors were allowed to accumulate to see if the wire had any definite fixed rate of stretch under a constant weight. The gage heights as published below have been adjusted from the measurements noted above. Records of flow may be found in the Twentieth Annual Report, Part IV, page 146. The following measurements were made during 1899 by E. W. Myers:

February 4, gage height, 7.03 feet; discharge, 4,590 second-feet.
May 27, gage height, 2.16 feet; discharge, 447 second-feet.
June 5, gage height, 2.51 feet; discharge, 610 second-feet.
October 12, gage height, 1.89 feet; discharge, 449 second-feet.
November 26, gage height, 1.82 feet; discharge, 290 second-feet.

Daily gage height, in feet, of Deep River at Moncure, North Carolina, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.03	4.58	6.91	7.12	2.99	2.84	1.52	4.54	0.85	0.83	12.74	2.77
2	3.21	5.00	6.25	4.70	2.85	2.61	1.36	4.36	.79	.78	5.86	1.85
3	3.41	6.78	6.39	4.52	2.56	3.45	1.34	3.46	.75	.88	4.23	1.83
4	3.27	7.06	13.25	5.16	2.51	3.13	1.18	3.08	.91	.79	3.48	2.19
5	2.79	16.40	14.43	8.64	2.29	2.49	4.20	1.46	.73	.87	3.04	2.15
6	2.47	20.48	15.77	6.18	2.25	1.95	2.42	1.20	.71	7.20	2.74	1.49
7	10.27	23.21	15.67	6.40	2.47	1.65	2.72	4.54	.89	6.49	2.24	1.27
8	9.13	25.92	13.62	17.76	8.85	1.49	2.11	4.11	1.19	6.70	1.91	1.19
9	7.71	30.90	10.61	15.04	6.09	1.58	2.19	4.15	1.10	7.11	1.86	1.11
10	5.59	18.70	7.39	8.28	4.43	2.55	2.10	3.37	1.82	3.96	.84	1.19
11	4.99	12.26	5.05	6.16	3.85	3.23	1.79	1.39	2.10	3.19	.89	4.03
12	5.83	7.19	4.41	5.40	5.89	4.72	1.67	1.41	2.55	1.97	1.09	5.95
13	6.07	6.98	4.67	4.86	7.99	3.78	1.34	1.25	2.04	1.72	1.02	4.69
14	9.79	6.06	3.91	4.48	9.23	3.40	1.19	1.21	4.86	1.59	1.09	3.39
15	13.07	5.10	21.19	3.76	5.99	2.56	1.09	1.29	1.96	1.31	.96	2.35
16	8.61	6.76	22.51	3.98	4.46	2.42	1.28	1.31	1.04	1.17	.98	1.39
17	7.91	16.20	16.21	4.10	3.97	2.40	.90	1.17	.93	1.27	1.08	1.34
18	6.93	21.26	9.99	4.04	3.75	1.68	1.14	1.09	.84	1.04	1.26	1.47
19	5.99	19.34	14.69	3.54	3.69	1.58	1.11	1.25	.87	1.06	1.14	1.39
20	4.73	15.30	15.31	3.32	3.05	1.49	1.02	.88	1.71	1.12	1.02	.83
21	3.15	9.92	9.02	3.46	2.89	1.50	1.02	.74	1.99	.97	.98	1.27
22	3.36	9.05	7.15	2.97	2.67	1.47	1.02	.78	1.49	.90	1.10	1.13
23	3.08	8.22	5.87	3.10	3.25	1.77	1.19	.90	1.17	.87	1.05	1.07
24	3.17	7.92	5.43	2.96	2.85	1.37	1.11	.95	.87	.85	1.04	1.19
25	3.25	6.24	4.91	2.97	2.75	1.55	1.52	1.06	2.34	.91	1.00	1.13
26	3.27	6.92	4.41	5.60	2.51	1.57	1.67	.84	1.53	.92	1.32	1.11
27	3.54	12.94	4.14	5.54	2.25	1.71	5.19	1.00	1.35	1.01	1.92	1.07
28	3.19	18.22	7.07	4.46	2.02	2.15	4.35	.96	1.09	.98	1.83	.95
29	2.55	.....	11.65	3.50	1.91	1.68	3.77	1.20	1.17	.94	3.78	1.03
30	2.21	.....	10.31	3.04	2.54	1.60	2.11	1.22	1.04	.89	2.84	.97
31	3.23	.....	8.44	.....	2.96	.....	6.28	.89	.....	1.13	.....	1.03

CAPE FEAR RIVER AT FAYETTEVILLE, NORTH CAROLINA.

Cape Fear River is formed by the junction of the Haw and Deep rivers near Moncure, Chatham County, North Carolina, and flows in a southeasterly direction, emptying into the Atlantic Ocean near Wilmington. Its watershed for the most part is flat and well covered with forest growth. Measurements are made on both the Haw and the Deep at Moncure, and on the Cape Fear at Fayetteville. The measurements are of value in the study of the valuable water powers of the Cape Fear and its tributaries. The gaging station described in the Eighteenth Annual Report, Part IV, page 54, is at the bridge of the Alantlc Coast Line, about a mile east of Fayetteville, North Carolina. The Weather Bureau has a gage fastened on the lower side of the east abutment of the covered highway bridge, this being about 400 feet above the railroad bridge, from which discharge measurements are made. The lower 29 feet of this gage consists of a rod divided into feet and tenths and firmly fastened to the abutment. Above the 29-foot mark the scale is painted on the rock. The observer is Frank Glover, who has charge of the steamboat landing just below the railroad bridge. For his convenience he has placed a subsidiary gage at the steamboat landing reading about the same as the official gage, and from this observations are taken. The channel is straight and the current moderately swift and not influenced by dams or other obstructions. The banks are high and the total flow of the river is in one channel, even during the highest floods. The bed is fairly constant. Records of flow may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 56; 1897, Nineteenth Annual Report, Part IV, page 93; 1898, Twentieth Annual Report, Part IV, page 145. The following measurements were made by E. W. Myers during 1899:

February 7, gage height, 46.50 feet; discharge, 61,921 second-feet.
May 24, gage height, 6.40 feet; discharge, 3,142 second-feet.
June 6, gage height, 4.20 feet; discharge, 1,577 second-feet.
October 13, gage height, 6.00 feet; discharge, 2,132 second-feet.
November 29, gage height, 9.65 feet; discharge, 7,742 second-feet.

Daily gage height, in feet, of Cape Fear River at Fayetteville, North Carolina, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.50	11.00	30.80	17.80	7.20	6.00	2.90	11.50	2.40	2.00	11.00	8.00
2	4.60	18.10	25.00	17.00	6.00	6.40	6.40	10.00	2.20	1.70	21.40	6.40
3	6.50	14.00	21.00	14.00	6.00	8.00	8.00	8.80	1.90	1.70	17.50	6.50
4	6.50	12.80	28.60	12.20	5.50	7.60	7.60	7.00	1.60	1.50	12.80	7.00
5	5.80	23.00	34.40	15.60	5.50	6.10	6.10	5.50	1.50	1.40	10.40	6.70
6	5.50	31.90	33.20	21.00	5.50	4.20	4.20	4.20	1.60	2.10	8.30	5.50
7	5.50	41.00	27.40	17.60	5.60	4.20	4.20	3.20	1.40	14.40	6.50	5.10
8	17.00	50.80	25.00	23.20	8.60	3.80	3.80	3.60	2.00	13.50	5.00	4.90
9	21.40	52.00	20.00	35.50	14.20	3.50	3.30	7.00	1.80	17.00	5.00	4.70
10	14.90	47.30	15.00	30.30	13.00	4.50	9.30	10.20	1.90	13.20	5.00	4.30
11	10.20	37.40	11.50	23.00	9.80	7.50	6.40	7.00	1.80	10.00	4.80	4.30
12	8.00	30.00	10.20	19.40	10.90	8.10	5.00	5.50	5.70	7.00	4.50	4.50
13	9.30	20.80	9.40	15.80	11.00	10.00	3.60	4.60	4.00	5.00	4.60	4.00
14	10.00	12.30	8.70	13.50	15.40	11.10	3.10	3.70	4.00	4.50	4.30	14.00
15	19.00	10.00	18.60	10.20	17.30	8.00	2.60	3.00	4.60	3.80	4.00	10.00
16	23.60	12.50	38.60	9.80	12.00	5.80	2.40	2.70	4.00	3.50	4.00	7.50
17	17.20	24.00	42.00	9.00	9.70	5.00	2.40	2.50	2.50	3.50	4.00	6.00
18	14.50	36.50	38.00	10.00	7.20	4.60	4.50	2.40	1.80	3.00	3.90	5.40
19	13.40	42.60	28.00	9.20	5.50	4.10	4.00	2.70	1.60	3.30	3.80	5.00
20	11.00	43.00	28.80	9.40	5.30	3.70	3.50	2.70	1.80	3.00	3.60	4.80
21	9.20	38.50	32.00	9.00	5.20	3.20	3.00	2.30	2.50	2.70	3.50	4.50
22	8.00	34.00	25.00	8.50	5.00	3.20	2.40	2.20	4.00	2.50	3.30	4.00
23	7.00	28.30	18.00	8.40	5.30	3.00	2.30	5.00	3.70	2.20	3.30	4.20
24	6.20	23.00	14.70	8.00	6.30	3.10	2.80	3.70	3.20	2.30	3.80	5.40
25	6.20	18.20	12.00	6.60	6.00	2.90	4.00	2.50	2.60	2.10	4.00	10.00
26	6.00	16.40	10.00	7.00	5.50	2.50	6.40	2.70	2.90	2.10	4.00	12.00
27	7.00	17.00	10.00	10.00	5.30	2.80	7.00	2.10	3.70	2.10	4.50	9.70
28	6.80	28.40	12.00	11.40	4.70	3.10	12.80	1.60	3.90	2.10	5.60	7.30
29	6.60	.....	17.80	10.00	4.20	3.50	11.70	1.60	3.00	2.10	10.00	6.60
30	6.60	.....	21.70	8.80	4.20	3.20	9.90	1.50	2.50	2.10	9.50	5.90
31	7.00	.....	19.20	.....	5.00	.....	7.60	2.90	.....	4.20	.....	.....

YADKIN RIVER AT SALISBURY, NORTH CAROLINA.

This river rises in the west-central part of North Carolina, flows easterly, and then turning abruptly south continues across the central part of North Carolina and through the northeastern part of South Carolina into the Atlantic Ocean. Throughout the upper part of its course the topography of its watershed is rough and mountainous, but as it approaches the ocean the land becomes flat and marshy. The upper portion of its watershed is well timbered. The drainage area is partly mapped on the Statesville, Hickory, Wilkesboro, Yadkinville, and Hillsville atlas sheets. There are a number of places where water powers may be developed, and measurements have been made to determine the available amount. A station has been established near Salisbury, North Carolina, and another one about 50 miles nearer its mouth, at Norwood, North Carolina. The Salisbury station, described in the Eighteenth Annual Report, Part IV, page 57, was established by C. C. Babb September 24, 1895, and is located at the Southern Railway bridge near Holtsburg, near the mouth of Grant Creek, and about 6 miles from Salisbury, North Carolina. The length of the wire gage is 55.10 feet. The observer is W. L. Owen, fireman of pumping station, located just below the bridge. The station is easily reached by private conveyance from Salisbury. Discharge measurements are made from the lower side of the deck bridge, the zero point being on the left bank. The channel is obstructed by three piers

with large rafts of driftwood lodged against each and sand bars below each. The channel is straight, current swift, and the bed rough and rocky. The banks are rather low, but all of the water passes beneath the bridge during floods. Records of discharge may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 59; 1897, Nineteenth Annual Report, Part IV, page 201; 1898, Twentieth Annual Report, Part IV, page 146. The following measurements were made by E. W. Myers during 1899:

Measurements of Yadkin River at Salisbury, North Carolina.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Sec.-feet.*	1899.	*Feet.*	*Sec.-feet.*
February 9	6.60	14,781	June 9	2.38	4,264
March 20	18.80	115,085	October 4	1.70	1,847
April 14	3.75	8,795	November 24	1.70	1,957
June 8	2.30	4,264	December 14	3.00	5,952

Daily gage height, in feet, of Yadkin River at Salisbury, North Carolina, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.00	3.20	4.70	4.30	3.10	2.40	2.20	2.80	2.00	1.60	2.00	1.90
2	2.00	3.00	4.00	3.90	3.10	2.90	2.10	2.30	2.10	1.60	2.20	1.90
3	2.10	2.90	6.10	3.80	3.10	2.60	2.10	2.20	2.20	1.60	2.20	1.90
4	2.00	2.90	8.00	4.10	3.10	2.60	2.50	2.00	2.10	1.60	2.40	1.80
5	3.10	7.50	8.00	4.20	3.00	2.50	3.20	2.00	2.10	1.70	2.20	1.80
6	4.00	8.75	7.15	4.70	2.90	2.40	2.50	1.80	1.90	1.70	2.00	1.80
7	10.20	10.10	5.90	4.80	3.20	2.40	2.30	1.80	1.80	1.80	1.90	1.80
8	5.90	9.20	4.10	7.80	4.40	2.40	2.30	2.30	1.70	2.90	1.90	1.70
9	4.80	6.30	3.90	5.90	4.00	2.40	2.20	2.10	1.70	3.00	1.80	1.70
10	4.00	4.00	3.70	4.70	3.50	3.10	2.20	2.00	2.20	2.40	1.70	1.70
11	3.00	3.30	3.50	4.20	3.40	3.30	2.10	2.00	2.00	2.10	1.70	1.70
12	4.40	3.40	3.40	3.80	3.30	3.80	2.10	1.90	1.99	1.90	1.70	2.00
13	4.00	2.90	3.30	3.80	4.10	4.80	2.00	2.10	1.90	1.90	1.70	3.80
14	4.50	2.90	5.20	3.80	4.10	3.90	2.00	2.00	1.70	2.00	1.70	3.40
15	4.40	2.20	8.50	3.70	3.60	3.20	1.90	1.90	1.70	1.90	1.70	2.90
16	4.10	3.00	12.40	3.70	3.10	2.60	1.90	1.90	1.69	1.80	1.70	2.10
17	3.70	5.10	7.90	3.60	3.00	2.50	1.90	1.80	1.60	1.80	1.70	2.00
18	3.50	6.00	6.70	3.50	3.00	2.40	2.30	1.70	1.60	1.80	1.70	1.90
19	3.20	5.00	12.00	3.40	2.90	2.40	2.20	1.70	1.50	1.80	1.70	1.90
20	3.10	4.60	17.80	3.40	2.80	2.30	2.10	1.80	4.20	1.80	1.70	1.90
21	2.80	4.00	13.75	3.40	2.70	2.30	1.90	1.60	2.90	1.80	1.70	1.70
22	2.90	3.90	6.50	3.30	2.70	2.30	1.90	1.60	2.20	1.80	1.70	1.70
23	2.80	3.60	5.30	3.20	2.90	2.30	1.90	1.60	1.90	1.70	1.70	1.70
24	2.90	3.10	4.80	3.20	3.00	2.20	1.90	1.50	1.70	1.70	1.70	2.00
25	2.80	3.10	4.40	3.30	2.80	2.20	2.00	1.50	1.70	1.70	1.70	2.40
26	2.80	3.00	4.30	4.10	2.70	2.80	2.70	1.50	1.70	1.70	1.70	2.40
27	2.80	5.40	5.40	4.10	2.70	3.00	4.30	1.60	1.70	1.70	1.80	2.10
28	2.90	7.80	5.40	3.80	2.60	2.00	3.20	2.00	1.60	1.70	1.80	1.90
29	2.80	.....	6.30	3.40	2.60	2.40	3.00	2.20	1.60	1.70	1.90	1.80
30	2.70	.....	5.30	3.30	2.60	2.20	2.80	2.20	1.50	1.70	1.90	1.80
31	3.30	.....	4.50	.....	2.50	.....	3.50	1.90	.....	1.70	.....	1.70

Yadkin River, after passing the State line into South Carolina, is known as Pedee River. The United States Weather Bureau has maintained a station at Cheraw, South Carolina, on Pedee River. The gage is a pine timber attached to the Cheraw toll bridge. The top of the rail on the Cheraw and Darlington Railroad bridge is 58 feet above zero of gage. The highest water was 37.3 feet on March 11, 1875; lowest, 0.0 feet, in August, 1866. The danger line is at 27 feet. The drainage area at this point is 6,960 square miles, according to

the United States Weather Bureau. The second river-height station maintained by the United States Weather Bureau at Smiths Mills, South Carolina, is 100 miles below Cheraw and 45 miles above the mouth of the river. The gage is a 1 by 6 inch pine timber attached to the central front wooden pier of the E. P. Smith wharf. The zero of the gage is 25 feet below the doorsill of the house adjoining the wharf. The highest water was 16 feet in September, 1893; the lowest, —0.4 foot, on October 22, 1895. The danger line is at 16 feet.

YADKIN RIVER AT NORWOOD, NORTH CAROLINA.

This station, described in the Eighteenth Annual Report, Part IV, page 60, was established by E. W. Myers September 1, 1896. It is at Blalocks Ferry, 1 mile above Richland Creek and about 2 miles from Norwood, North Carolina. The gage is a vertical rod divided into feet and tenths, and is securely spiked and braced to an overhanging tree near the ferry. The rod is referred to a bench mark consisting of a large nail driven into the root of a birch tree about 50 feet northwest of the rod. The zero of the gage rod is 5.93 feet below the bench mark. The river here is broad and shallow with smooth bottom of sand and gravel, giving a good section for discharge measurements, which are taken from the ferryboat. The channel is straight and free from all obstructions. The current is swift and the depth of the water uniform, except at a point about 100 feet from the right bank where the water is deep and very sluggish. The banks are low, and at the time of highest flood are overflowed for a distance of half a mile. The observer is W. B. Nichols, of Norwood, North Carolina, a farmer, who also carries the mail. Records of discharge may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 61; 1897, Nineteenth Annual Report, Part IV, page 203; 1898, Twentieth Annual Report, Part IV, page 147. Measurements made by E. W. Myers during 1899 are as follows:

April 9, gage height, 3.40 feet; discharge, 10,581 second-feet.
June 8, gage height, 1.95 feet; discharge, 4,474 second-feet.
June 9, gage height, 1.95 feet; discharge, 4,474 second-feet.
October 6, gage height, 1.35 feet; discharge, 2,629 second-feet.
October 6, gage height, 1.33 feet; discharge, 2,619 second-feet.
December 15, gage height, 2.23 feet; discharge, 6,299 second-feet.

The following table, computed by E. W. Myers, shows the comparative run-off of the Yadkin River at Salisbury and Norwood. At the former point the area drained is 3,399 square miles, and at the latter station 4,614 square miles. The table is of interest on account of the close results, especially in the run-off of second-feet per square mile between the two stations, which are about 50 miles apart and have a difference in drainage area of 1,215 square miles. The footnotes at the bottom of the table should be studied in the same connection, as

the two stations were not established at the same time, and in the first part of the record are not entirely comparable. The table should be compared with a similar table for the Catawba River at Catawba and Rock Hill stations, given on page 122.

Table showing comparative minimum flows for Yadkin River at Salisbury and Norwood, North Carolina.

Year.	Driest month.		Mean flow for driest month.		Mean flow for driest month per square mile.		Minimum flow for year.		Minimum flow for year per square mile.	
	Salisbury.	Norwood.	Salisbury.	Norwood.	Salisbury.	Norwood.	Salisbury.	Norwood.	Salisbury.	Norwood.
			Sec.-ft.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
1895	Oct.	(a)	1,426	(a)	0.42	(a)	1,400	(a)	0.41	(a)
1896	Aug.	Sept. b	2,411	b 2,409	.71	b 0.52	1,000	b 1,450	.29	b 0.31
1897	Sept.	Sept.	1,727	1,822	.51	.39	900	1,310	.26	.28
1898	June	June	1,832	2,626	.54	.57	1,100	c 1,380	.32	.30
1899	Sept. d	Oct.	2,332	2,836	.69	.61	1,300	1,790	.38	.39

a Station not established during this year.

b Not directly comparable. Station not established until September.

c Minimum flow not in month of lowest mean flow, but in July.

d Figures for Norwood station for September are as follows: Mean flow, 3,346 cubic feet per second, 0.725 second-feet per square mile; minimum flow, 2,080 second-feet, 0.451 second-feet per square mile.

NOTE.—For 1897, where the difference is most marked, there is a higher stage of water reported from the Salisbury station than at the Norwood station, the crest of the flood probably passing the latter station at night. Had this been noted, it would further increase the mean flow for this station.

Daily gage height, in feet, of Yadkin River at Norwood, North Carolina, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.80	3.00	4.50	.....	2.60	2.10	1.90	2.70	1.50	1.30	1.70	1.20
2	4.30	2.90	3.70	.....	2.50	2.20	1.80	2.20	1.70	1.20	1.90	1.20
3	3.80	2.50	4.30	.....	2.70	2.50	1.70	2.70	1.20	1.20	1.80	1.50
4	2.80	2.70	6.70	.....	2.60	2.10	1.70	1.70	1.80	1.20	1.70	1.50
5	2.50	8.00	7.50	.....	2.50	2.10	3.00	1.20	1.80	1.10	1.90	1.50
6	2.40	10.50	6.10	.....	2.40	2.00	3.00	1.60	1.70	1.30	1.80	1.40
7	7.80	10.20	4.10	.....	2.60	2.00	2.20	1.50	1.50	1.40	1.70	1.40
8	9.00	9.60	4.00	.....	3.20	1.90	2.00	1.50	1.40	2.00	1.70	1.30
9	7.00	7.40	3.80	3.40	3.50	2.00	2.00	1.80	1.80	2.20	1.80	1.30
10	3.80	4.60	3.40	3.00	3.00	2.10	1.90	1.70	1.70	2.40	1.40	1.40
11	3.10	3.20	2.00	2.90	3.00	3.40	1.90	1.60	1.90	2.10	1.40	1.40
12	3.00	3.10	2.10	2.80	2.80	3.50	1.60	1.50	1.70	1.70	1.40	2.40
13	2.90	3.00	2.40	2.80	4.50	3.40	1.60	1.80	1.50	1.40	1.40	3.10
14	4.20	2.40	3.10	2.70	4.00	3.80	1.60	1.70	1.60	1.30	1.40	3.10
15	4.50	2.30	8.10	2.70	3.50	3.00	1.50	1.60	1.50	1.50	1.40	2.40
16	3.90	5.60	10.40	3.40	2.80	2.50	1.50	1.50	1.40	1.50	1.40	2.10
17	3.80	5.80	10.30	3.00	2.50	2.20	1.50	1.50	1.20	1.50	1.30	1.80
18	3.30	6.90	8.80	2.80	2.40	2.10	1.60	1.40	1.50	1.40	1.30	1.30
19	3.10	5.60	(a)	2.80	2.20	2.00	1.80	1.40	1.30	1.40	1.20	1.20
20	2.80	5.00	.....	2.70	2.50	2.00	1.50	1.30	1.20	1.40	1.30	1.20
21	2.60	4.20	.....	2.70	2.30	1.90	1.50	1.30	3.00	1.40	1.40	1.50
22	2.50	3.60	.....	2.58	2.20	1.90	1.40	1.40	2.80	1.30	1.30	1.50
23	2.40	3.60	.....	2.50	2.40	1.90	1.40	1.30	1.70	1.30	1.40	1.50
24	2.30	3.40	.....	2.40	2.60	1.80	1.50	1.20	1.70	1.20	1.40	1.80
25	2.50	2.90	.....	2.30	2.50	1.70	1.70	1.20	1.40	1.30	1.30	2.10
26	2.40	3.80	.....	2.80	2.30	1.70	1.60	1.20	1.30	1.20	1.30	2.10
27	2.40	5.90	.....	3.50	2.20	2.40	4.00	1.20	1.30	1.20	1.30	1.70
28	2.30	7.60	.....	3.10	2.10	2.30	2.00	1.20	1.40	1.20	1.50	1.80
29	2.30	.....	.....	2.80	2.10	2.10	2.50	1.60	1.30	1.20	1.70	1.20
30	2.20	.....	.....	2.70	2.20	2.00	2.30	1.80	1.20	1.20	1.70	1.20
31	2.70	.....	.....	.....	2.20	.....	2.10	2.00	.....	1.70	.....	.....

a No readings March 19 to April 8; gage washed out by flood.

CATAWBA RIVER AT CATAWBA, NORTH CAROLINA.

This river rises in the west-central part of North Carolina and flows in a general southerly direction into South Carolina, where it empties into Santee River. At a number of points along this river there are water powers which may be developed. Near its source Catawba River flows through a mountainous country, which becomes flatter as the South Carolina line is approached. The greater part of its watershed is covered with woodland or forest. The drainage area above Catawba is entirely mapped on the Hickory, Morganton, Wilkesboro, Mount Mitchell, and Cranberry atlas sheets. Systematic measurements have been made on the Catawba at Catawba, North Carolina, and near Rockhill, South Carolina. The station at Catawba, as described in the Eighteenth Annual Report, Part IV, page 64, was established by E. W. Myers, July 4, 1896, at the Southern Railway bridge, about one-half mile from Catawba, North Carolina. The river is straight for several miles above and below the bridge; the current is swift and evenly distributed across the stream. The channel is obstructed by three piers, riprap, and two trestles of false work. At time of highest water the west bank overflows slightly and the sandy bed cuts out in places. The observer is C. A. Reed, jr., a clerk in the post-office at Catawba, North Carolina. Discharge measurements are made from the plank walk underneath the bridge. The railway bridge here is a deck bridge, and the gage was located on a footway which was laid along the lower system of bracing. When the station was visited, in October, 1899, it was discovered that the span on which the gage was located was to be removed, so it became necessary to move the gage rod, which was done as follows:

A small temporary gage was installed to discover any change in the stage of the river while the gage was being removed. The distance from the weight to the pointer on the wire was measured and found to be correct when the gage-reading was taken and recorded, as was also the reading of the temporary gage. The rod was then moved to the position which was chosen for it, and securely fastened to the guard rail on the downstream side and on the second span of the bridge from the west. The zero of the rod is over the center of the second floor beam from the west end of the second span from the west end of the bridge. From the zero of the rod to the outer rim of the pulley wheel is 2.6 feet. The small temporary gage was then read and it was found that the reading was unchanged, so the gage in its new position was given the same reading as it had before. The length of the wire rope from the end of the weight to the pointer on the wire was then measured and found to be 55.25 feet. Records may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 65; 1897, Nineteenth Annual Report, Part IV, page 214; 1898, Twentieth

Annual Report, Part IV, page 149. The following measurements were made by E. W. Myers during 1899:

February 24, gage height, 3.26 feet; discharge, 3,598 second-feet.
February 24, gage height, 3.28 feet; discharge, 3,690 second-feet.
June 10, gage height, 2.94 feet; discharge, 2,820 second-feet.
October 9, gage height, 2.36 feet; discharge, 1,716 second-feet.
November 23, gage height, 2.20 feet; discharge, 1,118 second-feet.
December 16, gage height, 2.66 feet; discharge, 2,153 second-feet.

Daily gage height, in feet, of Catawba River at Catawba, North Carolina, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.50	2.70	5.45	4.65	3.40	2.95	2.40	2.20	2.40	1.95	2.10	2.10
2	3.10	2.70	4.30	4.40	3.40	2.00	2.35	2.25	2.90	1.95	2.15	2.15
3	3.00	2.80	4.00	3.90	3.35	2.90	2.30	2.20	2.75	1.95	2.10	2.15
4	2.80	10.00	4.00	3.95	3.30	2.80	2.30	2.15	2.60	1.90	2.15	2.15
5	2.80	8.60	7.40	4.60	3.30	2.75	2.35	2.10	2.40	1.90	2.20	2.15
6	5.20	9.60	5.90	4.40	3.25	2.70	2.40	2.10	2.20	2.00	2.18	2.15
7	8.00	9.10	4.30	5.70	4.90	2.65	2.50	2.30	2.20	2.10	2.18	2.10
8	4.70	6.50	4.15	8.90	4.70	2.60	2.60	2.40	2.25	2.20	2.15	2.10
9	4.40	5.60	4.00	5.75	4.25	3.35	2.50	2.35	2.30	2.36	2.10	2.10
10	4.00	4.30	3.80	5.10	3.85	2.92	2.40	2.80	2.50	2.30	2.10	2.10
11	3.90	3.60	3.70	4.50	3.60	2.90	2.40	2.60	2.40	2.25	2.10	2.15
12	3.90	3.30	3.60	4.30	3.75	3.35	2.35	2.40	2.20	2.20	2.10	6.50
13	3.80	2.90	3.55	4.10	5.10	3.25	2.30	2.40	2.00	2 18	2.10	6.10
14	3.50	2.90	3.50	4.00	3.80	3.15	2.20	2.00	2.00	2.15	2.10	3.30
15	3.30	2.90	16.50	3.90	3.60	3.05	2.20	2.10	2.00	2.10	2.10	2.90
16	3.60	4.20	11.10	3.80	3.40	2.95	2.20	2.00	2.00	2.05	2.10	2.60
17	3.30	7.30	6.70	3.70	3.20	2.90	2.20	2.00	2.00	2.05	2.05	2.55
18	3.10	5.00	6.80	3.60	3.05	2.90	2.25	2.00	2.00	2.05	2.05	2.50
19	3.00	4.30	22.80	3.50	3.00	2.80	2.20	2.00	2.85	2.10	2.05	2.50
20	2.90	4.00	15.80	3.50	2.95	2.70	2.18	2.00	2.30	2.10	2.05	2.45
21	2.80	3.75	7.30	3.50	2.90	2.60	2.15	2.00	2.15	2.10	2.00	2.35
22	2.70	3.50	6.90	3.50	2.95	2.50	2.15	2.00	2.00	2.10	2.00	2.25
23	2.70	3.40	5.90	3.50	3.00	2.40	2.15	2.00	2.00	2.10	2.00	3.00
24	2.70	3.25	5.30	3.50	2.90	2.30	2.15	2.00	2.00	2.10	2.00	3.10
25	3.00	3.20	4.80	3.70	2.85	2.30	2.15	2.05	2.00	2.08	2.00	3.10
26	2.85	3.70	4.70	4.50	2.80	2.60	3.70	2.03	1.95	2.08	2.05	3.08
27	2.70	13.30	6.50	4.25	2.80	2.50	3.30	2.05	1.95	2.05	2.05	3.05
28	2.70	6.00	6.50	3.60	2.80	2.40	2.70	2.10	2.00	2.05	2.05	3.05
29	2.70	.....	6.00	3.40	2.80	2.40	2.40	2.25	2.00	2.08	2.10	3.00
30	2.70	.....	5.50	3.80	2.80	2.40	2.35	2.35	1.95	2.00	2.10	3.50
31	2.70	.....	5.00	.....	2.80	.....	2.30	4.00	.....	2.05	.....	3.65

CATAWBA RIVER AT ROCKHILL, SOUTH CAROLINA.

This station, described in the Eighteenth Annual Report, Part IV, page 61, was established by C. C. Babb September 3, 1895. It is located at the bridge of the Southern Railway, 3 miles south of Fort Mill, South Carolina, and is about 60 miles below the Catawba station. The gage is fastened to the upper side of the guard rail, the 2-foot mark of the rod being over the center of the second vertical of the second truss from the south end of the bridge. The bench mark is described in Water-Supply Paper No. 15, page 35. The length of the gage was verified December 18, 1899, when it was found to have stretched 0.4 foot. The gage heights as published are corrected for this error. This station is reached from Rockhill by private conveyance. The channel is straight, current swift, and flow uninterrupted. The banks are not subject to overflow and all of the water is confined to one channel. The bed of the stream is solid rock and very rough. The current is at an angle with the bridge. Altogether the section

is a poor one. W. A. Morris, a farmer at Rockhill, is the observer. Records of flow can be found as follows: 1896, Eighteenth Annual Report, Part IV, page 63; 1897, Nineteenth Annual Report, Part IV, page 214; 1898, Twentieth Annual Report, Part IV, page 150. The following measurements were made by E. W. Myers during 1899:

February 23, gage height, 3.10 feet; discharge, 8,086 second-feet.
June 13, gage height, 2.45 feet; discharge, 6,065 second-feet.
October 3, gage height, 1.60 feet; discharge, 2,104 second-feet.
December 18, gage height, 2.00 feet; discharge, 2,848 second-feet.

The table below was computed by E. W. Myers, and shows the comparative minimum flows of Catawba River at Catawba and Rockhill stations, which are about 60 miles apart. The drainage area at Catawba, North Carolina, is 1,535 square miles, and at the lower point, or Rockhill, South Carolina, it is 2,987 square miles. This table is comparable with the one for Yadkin River, shown on page 119, and it will be seen that the run-off per square mile does not vary to any greater extent than one would expect. The Catawba station was not established until the year following the one at Rockhill, so that the results can not be compared in the early part of the record. These facts are brought out in the footnotes at the bottom of the tables.

Table showing the comparative minimum flows for Catawba River, Catawba and Rockhill stations.

Year.	Driest month.		Mean flow for driest month.		Mean flow, driest month, per square mile.		Minimum flow for year.		Minimum flow for year per square mile.	
	Rockhill.	Catawba.	Rockhill.	Catawba.	Rockhill.	Catawba.	Rockhill.	Catawba.	Rockhill.	Catawba.
			Sec.-ft.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
1895..	Sept.a..	.....	1,318	.....	0.441	.....	1,300	.....	0.435	.....
1896..	Aug....	Oct	1,604	865	.54	0.56	b1,330	770	.445	0.501
1897..	Sept....	Sept....	1,817	1,017	.61	.66	c1,575	d850	.526	.553
1898..	June ...	June ...	2,091	1,069	.70	.69	1,600	910	.535	.592
1899..	Nov	Nov	2,492	1,340	.835	.873	2,300	1,220	.770	.793

a Seven days' record.
b Also in July, August, and September.
c Minimum occurred in January. September minimum was 1,700 second-feet, or 0.569 second-foot per square mile.
d Minimum in October. September minimum 900 second-feet, or 0.579 second-foot per square mile.

Daily gage height, in feet, of Catawba River at Rockhill, South Carolina, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.20	2.40	6.20	4.00	2.80	2.20	2.10	2.10	2.00	1.70	1.90	1.70
2	2.80	2.50	4.10	3.70	2.80	2.20	2.00	2.00	3.50	1.60	1.80	1.70
3	2.60	2.30	3.40	3.40	2.70	2.40	2.00	1.90	2.50	1.60	1.70	1.60
4	2.30	2.30	3.40	3.25	2.70	2.40	1.85	1.90	2.10	1.60	2.10	1.60
5	2.30	7.90	4.80	4.30	2.60	2.25	1.80	1.90	2.10	1.50	1.80	1.60
6	2.20	10.75	4.10	4.20	2.60	2.20	1.80	1.80	2.00	1.50	1.70	1.60
7	8.30	11.70	4.30	3.80	2.60	2.20	1.80	1.70	2.00	1.80	1.60	1.60
8	8.00	10.20	3.70	6.20	3.30	2.15	1.90	1.70	2.60	2.40	1.60	1.60
9	5.10	6.20	3.20	6.90	3.80	2.10	2.00	1.80	1.90	2.10	1.60	1.60
10	3.30	4.20	3.10	4.80	3.10	2.10	2.00	2.00	2.30	1.80	1.60	1.70
11	2.80	3.50	2.90	4.00	2.90	2.50	1.90	2.20	2.60	1.80	1.60	1.60
12	2.85	3.10	2.90	3.70	2.80	2.50	1.90	2.40	2.10	1.70	1.60	2.80
13	2.70	2.80	2.80	3.50	2.70	2.40	1.80	2.20	1.80	1.70	1.60	3.30
14	3.10	2.50	2.60	3.40	4.30	2.90	1.80	1.90	1.80	1.70	1.60	3.60
15	3.60	2.60	7.55	3.30	3.40	2.60	1.80	1.80	1.80	1.70	1.60	2.60
16	3.30	3.10	14.05	3.15	2.90	2.35	1.80	1.80	1.70	1.70	1.60	2.20
17	2.95	5.80	12.00	3.20	2.70	2.20	1.80	1.80	1.70	1.70	1.60	2.10
18	2.80	6.60	5.70	3.10	2.60	2.05	1.80	1.80	1.55	1.70	1.50	2.00
19	2.70	4.80	5.30	3.10	2.55	2.05	1.80	1.80	1.50	1.70	1.50	2.20
20	2.60	3.90	16.85	3.00	2.55	2.05	1.80	1.70	1.80	1.70	1.50	2.10
21	2.50	3.40	14.20	2.90	2.50	2.00	2.10	1.70	2.00	1.70	1.50	2.10
22	2.40	3.30	5.70	2.85	2.40	2.00	1.80	1.60	1.90	1.70	1.50	2.10
23	2.40	3.10	4.40	2.80	2.40	2.00	1.80	1.60	1.70	1.70	1.70	2.00
24	2.20	3.10	4.40	2.80	2.50	2.00	1.70	1.60	1.70	1.60	1.70	2.70
25	2.40	2.90	4.00	2.80	2.50	2.00	1.80	1.60	1.60	1.60	1.70	2.70
26	2.40	2.80	3.70	3.50	2.40	2.00	1.90	1.60	1.60	1.60	1.90	2.70
27	2.40	5.99	4.55	3.85	2.35	2.00	2.50	1.50	1.60	1.60	1.80	2.40
28	2.30	10.40	5.50	3.30	2.35	2.15	2.70	1.60	1.60	1.60	1.70	2.10
29	2.30	.....	6.20	3.00	2.35	2.20	2.05	2.20	1.70	1.60	1.70	2.10
30	2.30	.....	5.30	2.90	2.30	2.10	2.00	2.10	1.70	1.60	1.70	2.10
31	2.20	.....	4.40	.....	2.30	.....	2.20	1.90	.....	1.80	.....	2.00

Catawba River in South Carolina is known as Wateree River. It unites with Congaree River to form the Santee. The United States Weather Bureau has maintained a station at Camden, South Carolina, on Wateree River, 43 miles above its mouth. The gage is a pine timber attached to the central granite pier of the South Carolina and Georgia Extension Railroad bridge. The top of the rail on the bridge is 47.0 feet above zero of gage. The highest water recorded was 31.5 feet, in September, 1886; the lowest, 0.0 feet, in June, 1884. The danger line is at 24 feet. The drainage area at this point, according to the Weather Bureau, is 2,635 square miles.

BROAD RIVER AT GAFFNEY, SOUTH CAROLINA.

Broad River rises on the eastern slope of the Blue Ridge Mountains, near Hickorynut Gap, in the west-central part of North Carolina, and flowing in a general southeasterly direction unites with Saluda River above Columbia, South Carolina, to form the Congaree. The drainage area comprises about 4,950 square miles, of which 3,550 are in South Carolina and 1,400 in North Carolina, and is partly mapped on the Morganton, Mount Mitchell, and Saluda atlas sheets. The upper part of its basin is rough, broken country largely covered with forests. In South Carolina the topography is flatter and for the greater part the land is under cultivation. Broad River receives a number of important tributaries, but there are no towns of importance along it. There are a number of sites for the possible development of water

power along its course, the most important of which are described in the Nineteenth Annual Report, Part IV, page 215. Systematic measurements of the flow have been made at Gaffney, South Carolina, 15 miles below the North Carolina line, and at Alston, 20 miles above Columbia, South Carolina. The station at Gaffney, described in the Eighteenth Annual Report, Part IV, page 65, was established by E. W. Myers July 1, 1896, and was located at the Southern Railway bridge, about 3 miles from Gaffney, South Carolina. This station was maintained until October 25, 1898, when the gage rod was moved to Gaffneys Ferry, 200 yards above the bridge, as described in Water-Supply Paper No. 27, page 27. The bench mark is described in the same paper. The velocity is quite rapid, well distributed all the way across, and the channel is straight for some distance above and below the station. The ferryman, John W. Gaffney, Gaffney, South Carolina, was employed to take charge of the gage. The results of discharge measurements are found as follows: 1896, Eighteenth Annual Report, Part IV, page 66; 1897, Nineteeth Annual Report, Part IV, page 220. The following measurements were made by E. W. Myers during 1899:

February 10, gage height, 3.70 feet; discharge, 4,702 second-feet.
February 22, gage height, 2.25 feet; discharge, 4,497 second-feet.
April 15, gage height, 3.20 feet; discharge, 3,510 second-feet.
June 12, gage height, 2.40 feet; discharge, 2,496 second-feet.
October 4, gage height, 1.70 feet; discharge, 692 second-feet.
October 4, gage height, 1.70 feet; discharge, 662 second-feet.
December 17, gage height, 1.65 feet; discharge, 1,485 second-feet.

Daily gage height, in feet, of Broad River at Gaffney, South Carolina, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.50	2.40	5.00	3.90	2.80	2.10	1.80	1.90	2.50	1.30	1.60	1.40
2	2.40	2.40	3.90	3.50	2.80	2.10	1.80	1.80	2.00	1.20	1.70	1.40
3	2.20	2.30	3.50	3.40	2.60	2.00	1.70	1.80	1.90	1.40	1.80	1.50
4	2.10	2.30	3.40	3.60	2.50	2.10	1.70	1.70	1.70	1.30	1.60	1.50
5	2.00	5.80	3.40	4.90	2.70	2.10	1.70	1.60	1.60	1.30	1.60	1.40
6	2.80	8.20	3.50	3.60	2.70	1.90	1.60	1.60	1.50	1.70	1.50	1.30
7	8.40	10.20	3.30	4.50	2.60	2.00	1.70	1.50	1.20	1.60	1.60	1.40
8	5.40	7.20	3.10	6.40	2.50	2.00	1.70	1.50	2.00	1.70	1.50	1.40
9	4.60	.....	3.00	4.50	2.50	2.00	1.80	1.50	2.20	1.80	1.40	1.30
10	3.00	.....	3.00	4.00	2.40	2.00	1.80	2.00	1.90	1.80	1.50	1.30
11	3.10	.....	2.90	3.70	2.40	2.00	1.70	2.50	2.00	1.70	1.50	1.40
12	3.00	3.70	2.90	3.50	2.40	2.00	1.60	2.10	1.60	1.70	1.40	2.60
13	3.00	3.50	2.90	3.40	4.50	3.20	1.60	1.90	1.30	1.60	1.35	3.50
14	3.00	3.40	3.50	3.20	3.70	2.30	1.60	1.80	1.30	1.40	1.40	2.20
15	3.20	3.10	9.20	3.20	2.80	2.20	1.60	1.90	1.20	1.40	1.60	1.90
16	3.10	3.90	10.00	3.30	2.70	2.10	1.50	1.70	1.20	1.50	1.40	1.80
17	2.90	6.80	8.30	3.20	2.40	2.00	1.50	1.60	1.20	1.50	1.50	1.70
18	2.80	4.30	5.80	3.10	2.40	2.20	1.60	1.50	1.30	1.60	1.40	1.80
19	2.60	3.70	12.20	3.00	2.40	1.80	1.60	1.40	1.30	1.50	1.30	1.60
20	2.50	3.40	11.50	3.00	2.20	1.80	1.90	1.40	1.40	1.40	1.30	1.70
21	2.30	3.10	5.60	2.90	2.50	1.80	1.80	1.30	1.70	1.40	1.30	1.60
22	2.20	3.10	5.60	2.90	2.20	1.70	1.70	1.40	1.60	1.30	1.40	1.50
23	2.30	3.00	4.80	2.90	2.20	1.70	1.70	1.40	1.40	1.30	1.50	1.60
24	2.20	2.80	4.50	2.60	2.20	1.60	1.60	1.50	1.20	1.40	1.50	2.80
25	2.40	2.80	4.20	3.30	2.20	2.00	1.60	1.50	1.40	1.30	1.50	2.40
26	2.20	2.80	4.00	4.10	2.10	1.70	1.90	1.50	1.60	1.30	1.60	2.30
27	2.20	9.80	4.50	3.20	2.10	2.20	2.60	2.60	1.50	1.20	1.60	2.00
28	2.10	7.00	4.60	3.10	1.90	2.10	1.90	1.90	1.30	1.30	1.60	1.70
29	2.20	.....	5.50	2.90	2.00	2.00	1.90	2.00	1.40	1.30	1.50	1.60
30	2.20	.....	4.00	2.80	2.20	1.80	1.80	1.90	1.70	1.40	1.50	1.60
31	2.30	.....	4.00	.....	2.10	.....	1.80	2.30	.....	1.50	.....	1.50

BROAD RIVER AT ALSTON, SOUTH CAROLINA.

This station, described in the Eighteenth Annual Report, Part IV, page 67, was established by E. W. Myers, July 3, 1896, and is located at the Southern Railway bridge near Alston, South Carolina, and 60 miles below the Gaffney station. The length of the wire gage is 42.65 feet. The gage was verified December 19, 1899. The section here is not a good one, being broken by the foundations of an old bridge crossing at the same place as the present one. The bed is flat, muddy, and somewhat shifting. The river is straight for a long distance above and below the station. The current is swift and the velocity fairly uniform across the section. The observer is D. R. Elkin, a farmer of Alston, South Carolina. Records of discharge may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 68; 1897 and 1898, Twentieth Annual Report, Part IV, page 151. The following measurements were made by E. W. Myers in 1899:

February 19, gage height, 10.15 feet; discharge, 28,930 second-feet.
June 14, gage height, 4.33 feet; discharge, 6,289 second-feet.
October 2, gage height, 2.14 feet; discharge, 1,645 second-feet.
December 19, gage height, 2.91 feet; discharge, 3,319 second-feet.

Daily gage height, in feet, of Broad River at Alston, South Carolina, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.42	4.78	11.50	8.83	4.30	3.32	2.77	3.10	4.50	2.20	4.47	2.90
2	3.88	4.60	8.00	6.74	4.10	3.30	2.74	3.00	4.45	2.12	3.10	3.16
3	3.90	4.30	6.54	5.51	4.09	3.20	2.50	2.55	3.55	1.97	2.87	3.14
4	3.43	4.30	7.42	5.30	4.00	3.10	2.76	3.08	3.65	2.20	3.88	2.80
5	3.35	6.90	7.42	6.10	3.99	3.10	2.53	2.50	3.00	2.34	2.74	2.66
6	3.47	13.00	10.51	6.10	3.99	2.80	2.63	3.00	2.90	6.28	2.62	2.82
7	9.50	18.00	6.20	5.61	4.11	2.90	2.60	2.80	2.78	3.52	2.37	2.70
8	14.00	18.50	5.53	8.33	4.20	2.89	2.62	2.10	3.45	4.18	2.64	2.65
9	9.40	12.90	5.11	9.00	3.98	2.90	2.73	2.80	3.43	3.22	2.58	2.71
10	7.10	9.50	4.90	7.14	3.82	2.88	2.90	2.65	3.52	2.90	2.51	2.66
11	5.78	6.78	4.79	6.13	3.63	2.89	2.60	2.75	9.30	2.86	2.50	2.53
12	7.20	5.80	4.71	5.88	3.69	3.40	2.48	4.50	4.40	2.68	2.56	6.48
13	7.35	5.40	4.42	5.40	3.70	3.10	2.43	3.34	3.60	2.58	2.78	8.13
14	6.71	4.86	4.59	5.20	3.88	4.28	2.30	2.80	2.81	2.60	2.23	5.13
15	7.51	4.54	6.28	5.08	4.68	3.70	2.34	2.55	2.62	2.58	2.50	4.42
16	6.10	8.33	14.40	4.90	3.98	3.35	2.33	2.55	2.60	2.43	2.60	3.70
17	6.20	15.30	15.39	4.87	3.62	3.00	2.24	2.55	2.40	2.21	2.57	3.34
18	5.32	12.69	10.50	4.65	3.52	3.40	2.09	2.23	2.30	2.52	2.58	3.07
19	4.70	10.10	8.00	4.69	3.40	3.10	2.28	2.20	2.35	2.54	2.51	2.91
20	4.33	6.84	15.30	4.68	3.45	2.92	2.10	2.00	2.60	2.49	2.43	3.22
21	4.11	6.23	13.94	4.54	3.30	2.84	2.83	2.15	2.63	2.57	2.29	3.08
22	4.00	6.52	8.94	4.41	3.40	2.82	2.52	2.14	2.60	2.42	2.52	2.90
23	3.82	5.61	7.00	4.30	3.43	2.79	2.80	2.40	2.50	2.20	4.71	3.60
24	4.10	5.11	7.12	4.40	3.88	2.73	2.17	2.30	2.39	2.15	3.61	7.32
25	4.20	4.61	6.40	4.13	3.72	2.51	2.40	3.40	2.30	2.45	3.10	8.20
26	4.55	4.62	5.90	6.61	3.82	2.60	2.95	2.35	2.08	2.40	5.54	4.44
27	4.00	13.72	5.80	6.64	3.30	2.70	6.25	3.55	2.60	2.39	4.25	3.00
28	3.80	17.98	7.30	5.80	3.30	3.78	4.72	5.55	2.35	2.41	3.50	3.76
29	3.90	.....	7.72	4.70	3.28	3.30	3.80	4.70	2.29	2.40	3.30	3.75
30	4.10	.....	7.43	4.40	3.11	2.93	2.09	4.28	2.47	2.30	3.04	.....
31	4.50	.....	6.84	.....	3.11	.....	3.15	4.50	.....	4.57	.....	.....

Broad River joins Saluda River at Columbia, South Carolina, to form Congaree River. The United States Weather Bureau has maintained river-height observations at Columbia, South Carolina. The gage rod is painted on the first stone pier from the eastern shore

of the Gervais street toll bridge. The bench mark is the track of the South Carolina and Georgia Extension Railroad at the Union Station, and is at an elevation of 102.59 feet above the zero of the gage. The high-water mark is 34.4 feet, and was reached in September, 1852; the lowest, —0.4 foot, on January 20, 1893. The danger line is 15 feet. The drainage area above the station, according to the United States Weather Bureau, is 7,300 square miles.

Santee River is formed by the junction of Wateree and Congaree rivers. The United States Weather Bureau has maintained a gage on Lower Santee River at St. Stephen, South Carolina, 50 miles above its mouth. The gage rod is attached to the downstream side of the central granite pier of the railroad bridge. The top of the rail on this bridge is 31 feet above zero of gage. The high-water mark is 20.2 feet, and was reached on September 18, 1888; the lowest, 1.3 feet, on October 6, 1895. The danger line is at 12 feet. The area drained at this point, according to the United States Weather Bureau, is 13,600 square miles.

SALUDA RIVER AT WATERLOO, SOUTH CAROLINA.

Saluda River rises in the mountains between North and South Carolina, flows in a southeasterly direction, and unites, near Columbia, South Carolina, with the Broad, to form the Congaree. The drainage area is partly mapped on the Saluda, Pickens, Pisgah, and Abbeville atlas sheets. Measurements have been made on the Saluda to determine the available water power. The station was established by E. W. Myers, August 30, 1896, and is described in the Eighteenth Annual Report, Part IV, page 68. It is 1 mile below the mouth of Reedy River, at the Charleston and Western Carolina Railway bridge, about 3 miles from Coronaca Station, South Carolina. The length of the gage wire is 47.00 feet. The length of the gage was verified December 19, 1899. The river here is straight for several hundred yards above and below the bridge. The flow is probably influenced by dams some miles above. The bed of the stream is of sand and mud and liable to change during high water. The banks are low, the right bank being subject to overflow. The observer is R. N. Cunningham, storekeeper and farmer at Waterloo, South Carolina. The locality is reached by private conveyance from Greenwood, South Carolina. The discharge measurements are made from the railroad bridge. Records of results may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 68; 1897, Nineteenth Annual Report, Part IV, page 221; 1898, Twentieth Annual Report, Part IV, page 153. The following measurements were made by E. W. Myers during 1899:

February 20, gage height, 7.60 feet; discharge, 3,350 second-feet.
June 14, gage height, 5.30 feet; discharge, 1,740 second-feet.
October 1, gage height, 3.65 feet; discharge, 604 second-feet.
December 19, gage height, 4.00 feet; discharge, 995 second-feet.

Daily gage height, in feet, of Saluda River at Waterloo, South Carolina, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	6.00	5.75	12.80	8.75	6.00	4.75	4.95	3.80	3.90	3.65	4.75	4.60
2	4.65	5.40	8.90	7.55	5.90	4.40	3.95	3.70	5.20	2.85	4.50	4.45
3	5.05	5.60	7.65	7.05	5.80	5.15	3.85	3.65	5.25	3.60	4.65	3.80
4	4.90	6.25	7.60	7.15	5.60	4.35	4.20	3.70	3.25	4.35	4.40	3.05
5	4.80	6.85	8.00	7.30	6.00	4.15	3.20	4.75	3.95	4.20	3.80	3.90
6	5.00	10.60	8.10	7.60	5.95	5.05	3.75	4.00	3.85	5.50	2.90	4.25
7	14.00	18.50	7.25	7.20	6.15	4.10	3.80	3.80	3.70	4.50	4.35	3.80
8	14.30	17.35	6.70	7.95	5.80	4.00	4.85	3.90	4.10	5.65	4.30	3.85
9	6.05	12.70	6.50	8.35	5.85	3.80	4.65	4.60	4.85	4.00	4.35	4.25
10	7.05	8.60	6.70	7.40	6.55	3.70	3.45	4.00	3.85	4.00	4.35	3.45
11	6.50	7.60	6.30	6.90	5.50	3.75	3.70	5.50	6.60	4.10	4.15	3.00
12	6.90	7.10	6.45	6.95	5.30	5.85	3.70	4.90	5.50	4.00	3.70	5.90
13	7.50	7.00	6.45	6.75	5.20	5.50	3.60	4.50	3.95	4.00	2.90	7.10
14	7.80	5.60	6.25	6.65	4.95	5.55	3.60	3.20	3.80	4.65	4.00	5.85
15	7.45	6.50	10.30	6.30	4.80	4.45	4.75	3.65	4.50	4.10	4.45	5.00
16	6.95	12.55	15.35	6.55	4.60	4.25	4.50	3.65	4.10	3.00	4.35	4.85
17	6.65	15.20	13.85	6.35	4.70	4.90	3.60	3.55	3.50	4.20	4.05	4.45
18	6.25	13.10	10.30	6.25	4.55	4.60	3.50	4.55	2.85	4.00	4.25	4.10
19	6.30	8.60	9.75	6.45	4.50	4.65	3.60	4.15	3.95	4.75	3.70	4.75
20	5.90	7.40	11.98	6.30	5.15	4.05	3.55	3.45	3.90	4.70	2.95	3.90
21	5.40	7.60	13.18	6.20	4.60	4.10	4.45	2.70	3.90	5.45	3.95	4.50
22	5.85	7.45	8.75	5.55	5.05	3.75	4.50	4.20	3.90	3.20	4.05	4.55
23	5.70	9.85	8.65	5.90	4.50	3.65	3.60	3.70	4.80	3.00	6.45	4.30
24	5.45	6.55	8.90	6.15	4.40	4.90	2.90	3.75	3.60	4.15	4.40	7.15
25	5.50	6.35	7.80	7.90	4.35	4.10	4.75	3.70	2.90	4.35	4.85	5.15
26	5.20	6.70	7.55	8.10	4.30	3.60	5.10	4.35	3.90	4.55	5.25	4.75
27	5.00	17.55	7.05	7.15	5.15	4.15	5.40	5.00	4.35	4.55	4.15	4.95
28	6.75	15.60	7.35	6.55	5.10	4.05	5.00	4.75	4.45	4.20	5.05	4.55
29	6.55	.....	7.95	6.00	3.75	4.20	5.45	4.35	3.80	3.83	5.00	4.15
30	4.10	.....	7.25	6.10	4.15	3.80	5.40	4.80	4.00	2.95	4.15	4.75
31	5.80	.....	9.35	.....	4.15	.....	3.80	4.40	.....	4.40	.....	4.40

TUGALOO RIVER AT MADISON, SOUTH CAROLINA.

This river is formed by the junction of the Tallulah and Chattooga rivers, which have their sources in the Blue Ridge Mountains. The basin is largely covered with an original growth of oak, and is extremely wild and picturesque. The drainage area is mapped on the following atlas sheets: Nantahala, Dahlonega, Walhalla, and Cowee. There are many beautiful falls in this watershed, the most noted of which are Tallulah Falls, with a drop of 335 feet in four successive leaps, the total fall in 2⅔ miles being 525 feet; and Toccoa Falls, on Toccoa Creek, with a vertical drop of about 190 feet. This latter stream should not be confused with Toccoa River, a tributary of Hiwassee River, and on which a gaging station is maintained at Blue Ridge, Georgia. The gaging station on Tugaloo River was established July 19, 1898, at Cooks Ferry, about one-half a mile from Madison, South Carolina, one mile below the Southern Railway bridge over Tugaloo River and 2 miles above the mouth of Chauga Creek. The gage is a 2 by 4 inch scantling 10 feet long, nailed to a sycamore tree on the right bank at the ferry landing. The bench marks are on the left bank of the river, the first being on a willow tree at the ferry landing, and consisting of three large nails 3.00 feet above zero of gage; the second is on the same tree, being one nail 6.00 feet above zero of gage; the third is a large nail in a sycamore tree at the ferry landing 12.00 feet above the zero of the gage. Discharge measurements are made from a boat held in place by the ferry rope stretched across the

river. The results of the measurements are given in the Twentieth Annual Report, Part IV, page 162. The following measurements were made by Max Hall and others in 1899:

April 21, gage height, 4.50 feet; discharge, 2,604 second-feet.
May 22, gage height, 3.20 feet; discharge, 1,687 second-feet.
June 20, gage height, 2.10 feet; discharge, 1,325 second-feet.
September 12, gage height, 1.00 foot; discharge, 734 second-feet.
October 4, gage height, 0.70 foot; discharge, 512 second-feet.

A number of discharge measurements were made on various tributaries of Tugaloo River during the fall of 1899. A measurement of Tallulah River above the falls at the wagon bridge at Tallulah Falls, Georgia, was made October 3, when the discharge was found to be 153 second-feet; a second measurement was made November 25, giving a discharge of 188 second-feet. Two discharge measurements were made on Toccoa Creek, above the falls, 2½ miles from Toccoa, Georgia, on October 4; they were made at different sections on the river, and gave 5.7 and 5.9 second-feet, respectively. Chauga Creek enters the Tugaloo about 2 miles below the gaging station. A measurement was made on this stream at the wagon bridge near its mouth at Madison, South Carolina, on October 4, when the discharge was found to be 99 second-feet.

Daily gage height, in feet, of Tugaloo River at Madison, South Carolina, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.10	3.90	6.60	6.40	4.30	2.50	1.70	1.40	3.10	0.70	0.90	1.60
2	3.40	3.40	5.90	5.90	4.20	2.40	1.60	1.40	2.70	.70	.80	1.10
3	3.30	3.50	5.80	5.70	4.10	2.40	1.60	1.30	3.30	.70	.80	1.10
4	3.20	7.60	5.40	5.90	4.00	2.30	1.50	1.20	1.90	.70	.80	1.00
5	3.20	6.80	6.90	6.00	4.30	2.50	1.50	1.10	1.70	.80	.80	.90
6	6.45	11.85	6.00	5.60	4.10	3.30	1.60	1.10	1.40	.90	.70	.90
7	5.80	12.70	5.50	7.80	4.80	2.20	1.90	1.10	1.30	.80	.70	.90
8	4.60	8.80	5.20	8.70	4.00	2.20	1.60	1.00	1.20	3.30	.70	.80
9	4.20	6.80	5.20	6.80	3.80	2.10	1.60	1.00	1.20	2.50	.70	.80
10	3.90	5.80	4.90	6.20	3.70	2.00	1.60	1.40	1.10	1.50	.70	.80
11	4.20	5.50	4.80	5.80	3.70	2.20	1.50	1.30	1.10	1.00	.70	.90
12	4.10	5.30	4.70	5.50	3.60	3.90	1.40	1.00	1.00	.90	.70	12.30
13	3.90	8.40	4.20	5.30	3.60	5.30	1.30	.90	.90	.90	.70	8.45
14	4.00	4.40	8.05	5.20	3.40	3.50	1.30	1.00	.90	.80	.70	3.10
15	4.50	4.50	16.15	5.00	3.30	2.80	1.30	1.00	.80	.80	.70	2.50
16	4.00	5.60	13.80	5.10	3.20	2.40	1.20	1.00	.80	.80	.70	2.00
17	3.90	5.60	8.40	4.90	3.20	2.50	1.20	1.20	.80	.80	.70	1.80
18	3.70	5.00	6.90	4.80	3.10	2.40	1.20	1.00	.80	.90	.70	1.60
19	3.40	4.80	16.15	4.80	3.20	2.20	1.10	.90	.80	1.00	.70	1.60
20	3.40	4.60	11.60	4.60	3.00	2.10	1.20	.80	.90	1.00	.70	1.50
21	3.30	4.50	8.40	4.50	2.90	2.00	1.20	.80	.90	.90	.70	1.60
22	3.20	4.50	7.60	4.40	3.10	2.90	1.40	.80	.80	.90	.80	1.40
23	3.10	4.40	8.40	4.80	3.00	2.90	1.30	.90	.80	.90	.90	1.30
24	3.20	4.30	7.30	4.20	2.80	2.80	1.70	.80	.80	.80	1.10	5.00
25	3.40	4.10	6.80	6.80	2.70	2.00	1.40	.90	.80	.80	.90	3.40
26	3.20	6.50	6.40	6.00	2.70	1.80	4.10	.80	.90	.80	1.60	2.40
27	3.20	9.80	6.20	5.20	2.60	2.10	4.20	1.20	.90	.80	2.60	2.00
28	3.10	8.10	6.10	4.80	2.60	2.10	2.40	1.00	.80	.80	1.70	1.90
29	3.00	.....	6.80	4.60	2.60	2.00	2.90	.90	.80	.90	1.30	1.80
30	2.90	.....	6.00	4.40	2.50	1.80	1.90	1.40	.70	.90	1.10	1.60
31	3.10	.....	6.90	.....	2.50	.....	1.60	6.50	.....	.80	.....	1.40

SAVANNAH RIVER AT CALHOUN FALLS, SOUTH CAROLINA.

Savannah River is formed by the junction of Seneca and Tugaloo rivers about 100 miles above Augusta, Georgia. The headwater tributaries have their sources in the Blue Ridge Mountains in North and South Carolina and Georgia, where more than one-fifth of the territory is in original oak forest. The drainage area is partly mapped on the following atlas sheets; Pisgah, Cowee, Dahlonega, Walhalla, Pickens, Abbeville, Elberton, Nantahala, and Carnesville. A large number of fine water powers occur on the tributaries and along the main river, the most noted being at Tallulah Falls on Tallulah River, 335 feet in height, there being a total fall of 525 feet in a distance of 2⅞ miles. In order to determine the value of these waterpowers, systematic measurements were begun at Calhoun Falls, South Carolina, on August 4, 1896. This station, described in the Eighteenth Annual Report, Part IV, page 73, is at the Seaboard Air Line bridge, across Savannah River, above the mouth of Beaverdam Creek and below Rocky River, and about 3 miles west of the town of Calhoun Falls, South Carolina. The river here is divided into two channels by a large island containing several hundred acres. The east channel is a good section at ordinary stages, but at lowest water the current is very sluggish. The west channel, which is the main river, is obstructed by some very small islands and old cofferdams about the two piers, otherwise the section is a good one. The bed is rocky and constant. The wire gage is on the west channel, center span; its length is 65.40 feet. One bench mark on the top of the iron stringer under the cross-ties near the gage is 54.00 feet above the datum of the gage; the other is on the top of the first pier on east side of west channel, and is 30.85 feet above zero of gage. Zero of gage is 354.5 above sea level. The gage was verified on March 4, 1899. The observer is Peter J. Pfeiffer, a farmer at Calhoun Falls, South Carolina. Records of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 75; 1897, Nineteenth Annual Report, Part IV, page 224; 1898, Twentieth Annual Report, Part IV, page 164. The following measurements were made by B. M. Hall and Max Hall during 1899:

March 4, gage height, 4.77 feet; discharge, 12,076 second-feet.
May 16, gage height, 3.45 feet; discharge, 5,258 second-feet.
September 28, gage height, 2.30 feet; discharge, 2,057 second-feet.
November 10, gage height, 2.25 feet; discharge, 2,089 second-feet.

Daily gage height, in feet, of Savannah River at Calhoun Falls, South Carolina, for 1899.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	6.60	4.00	3.30	3.20	3.30	3.00	2.20	2.60	2.70
2	.....	5.00	3.90	3.20	3.00	3.10	2.90	2.10	2.50	2.80
3	.....	4.85	3.80	3.20	2.90	3.00	2.90	2.10	2.50	2.90
4	4.75	4.90	3.80	3.20	2.70	2.90	2.80	2.20	2.40	2.70
5	4.95	4.75	3.70	3.10	2.70	2.80	2.70	2.40	2.40	2.60
6	4.65	4.70	3.90	3.00	2.60	2.70	2.90	3.00	2.40	2.60
7	4.40	4.75	3.90	2.90	2.70	2.60	2.90	2.80	2.50	2.60
8	4.35	4.65	3.80	3.00	2.70	2.60	3.00	3.90	2.40	2.50
9	4.25	5.60	3.80	3.30	3.00	3.00	3.00	3.50	2.30	2.50
10	4.20	5.10	3.70	3.20	2.90	2.90	2.90	3.20	2.20	2.40
11	4.05	4.95	3.70	3.40	2.80	2.80	3.20	3.00	2.20	2.50
12	3.90	4.80	3.70	3.50	2.80	2.80	3.00	2.70	2.10	4.90
13	4.00	4.70	3.60	5.00	2.70	2.70	3.00	2.50	2.10	5.00
14	4.00	4.50	3.60	3.90	2.60	2.70	2.90	2.40	2.00	3.80
15	5.35	4.30	3.50	3.70	2.50	2.60	2.90	2.30	2.10	3.50
16	13.60	4.00	3.40	3.60	2.40	2.60	2.80	2.40	2.10	3.30
17	9.00	3.90	3.40	3.60	2.40	2.60	2.70	2.40	2.10	3.10
18	6.90	3.70	3.40	3.50	2.30	2.60	2.60	2.30	2.00	3.00
19	7.00	3.70	3.50	3.30	2.40	2.50	2.60	2.30	2.00	3.00
20	9.00	3.50	3.50	3.20	2.30	2.50	2.90	2.40	2.00	2.90
21	7.05	3.40	3.40	3.10	2.20	2.60	2.90	2.30	2.10	2.90
22	5.00	3.20	3.50	3.00	2.30	2.80	2.80	2.30	2.10	2.80
23	5.00	3.00	3.70	3.00	2.30	3.00	2.60	2.30	2.30	2.70
24	4.90	2.90	3.55	2.90	2.30	2.90	2.50	2.20	2.30	2.90
25	5.00	4.00	3.50	2.90	2.40	2.70	2.40	2.20	2.40	3.80
26	5.10	4.60	3.40	3.00	2.70	2.70	2.60	2.20	4.00	3.50
27	4.95	5.10	3.25	3.90	2.70	2.80	2.40	2.10	3.40	3.50
28	4.85	5.00	3.20	4.00	5.00	3.00	2.30	2.10	3.20	3.60
29	6.95	4.70	3.20	3.60	3.50	2.90	2.30	2.20	2.90	3.70
30	5.10	4.10	3.10	3.30	3.60	3.50	2.20	2.30	2.80	3.60
31	7.00	.....	3.30	.....	3.40	3.20	.....	2.50	.....	2.90

SAVANNAH RIVER AT AUGUSTA, GEORGIA.

Observations of river height have been maintained since 1875 by the city of Augusta, at the city highway bridge. The results have been printed in a volume entitled "Stages of water at river stations," prepared by the United States Weather Bureau. Those for 1875 to 1889 are given in Part III, those for 1890 to 1892 in Part IV, and for 1893 to 1895 in Part V of the above-mentioned publication. The gage consists of a vertical timber fastened to the pier and graduated to feet and inches. Readings are made four times a day by J. M. Youngblood, keeper of the city bridge, usually at 6 a. m., 12 m., 6 p. m., and 9 p. m. The 6. a. m. readings are those used by the Weather Bureau, and are here given, excepting September, October, and November, when the average of all four readings is given, since at that season nearly all of the water passes through the factory wheels above the gage. The channel is straight and without obstructions; the banks are moderately high, but are liable to overflow at the highest floods. Bed is fairly constant. Records of measurement may be found as follows: 1875 to 1891, Fourteenth Annual Report, Part II, page 147; 1891 to 1896, Eighteenth Annual Report, Part IV, page 75; 1897, Nineteenth Annual Report, Part IV, page 227; 1898, Twentieth Annual Report, Part IV, page 165. The following measurements have been made by B. M. Hall and his assistants during 1899:

Measurements of Savannah River at Augusta, Georgia.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Sec.-feet.*	1899.	*Feet.*	*Sec.-feet.*
March 17	25.20	60,716	May 29	7.60	6,271
March 18	20.80	35,971	July 1	7.22	5,391
May 8	9.70	10,860	August 3	6.68	4,226
May 9	9.50	9,908	October 10	12.48	14,613

Daily gage height, in feet, of Savannah River at Augusta, Georgia, for 1899. (*a*)

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	8.5	12.7	28.8	19.5	9.6	7.9	7.2	7.4	13.9	5.0	6.2	7.8
2	10.8	13.0	21.0	18.9	9.5	8.4	6.7	6.7	10.9	5.0	6.4	6.9
3	10.3	14.3	16.2	15.3	9.3	7.6	6.2	6.3	9.1	5.5	6.3	5.8
4	9.0	15.8	14.2	13.2	9.3	7.5	6.0	6.3	8.0	5.6	5.8	7.0
5	8.5	14.5	13.7	12.9	9.2	7.2	6.0	6.0	7.5	5.8	5.6	8.7
6	8.5	20.7	16.2	13.0	9.8	7.3	6.0	5.9	6.9	11.8	5.8	6.7
7	12.8	28.0	15.2	12.2	10.3	7.3	5.8	5.7	6.6	9.6	5.9	6.3
8	22.9	31.0	13.3	12.4	10.4	7.0	6.7	5.5	7.4	10.5	5.8	6.3
9	19.2	29.9	12.2	15.5	9.7	7.0	7.0	5.7	7.0	14.1	5.9	6.1
10	14.3	22.9	11.8	14.2	9.1	6.9	8.3	6.0	7.0	12.1	5.8	6.0
11	12.8	18.3	11.5	12.8	8.8	7.3	7.8	5.7	8.7	8.5	5.5	5.9
12	17.3	14.7	11.2	12.0	8.5	6.9	6.5	8.0	9.3	7.3	5.6	5.9
13	17.4	13.7	11.2	11.5	8.5	7.5	6.0	8.3	8.6	6.9	5.6	6.3
14	15.3	12.9	11.1	11.3	8.5	9.7	6.0	6.4	6.9	6.4	5.7	10.7
15	15.4	12.3	11.0	11.0	8.3	9.7	6.0	6.0	6.3	6.0	6 1	14.5
16	14.5	14.4	18.8	10.8	8.2	8.2	6.0	5.5	5.8	6.3	5.8	10.5
17	17.3	25.0	25.5	10.5	8.2	8.0	5.7	5.4	5.6	6.0	5.8	8.5
18	16.8	24.3	21.5	10.5	8.0	8.7	5.6	5.0	5.2	6.0	5.8	7.5
19	13.9	19.1	17.1	10.2	8.0	7.9	5.8	5.0	5.4	6.3	5.4	7.3
20	11.7	15.3	20.0	10.5	7.9	7.3	5.7	5.8	5.7	6.1	5.7	7.0
21	10.7	13.5	22.5	10.4	7.9	7.3	5,5	4.0	6.0	6.5	5.7	6.8
22	10.0	14.7	17.1	10.0	7.8	7.0	5.3	4.7	6.6	6.7	5.8	6.9
23	9.9	14.3	15.8	9.9	7.7	6.7	5.8	5.3	6.0	6.0	5.8	7.4
24	11.4	13.0	15.5	9.6	8.2	6.7	5.8	4.8	5.4	6.0	7.0	9.3
25	11.9	11.7	15.5	10.0	8.0	6.5	5.7	5.7	5.9	5.8	8.3	13.8
26	10.8	11.5	13.8	11.5	7.8	6.3	6.0	5.6	5.6	5.8	9.2	12.3
27	10.3	17.7	14.0	13.0	7.6	6.7	7.0	7.0	5.3	5.6	11.3	9.8
28	10.0	29.6	13.5	11.2	7.4	7.5	11.7	13.3	5.8	5.7	9.8	8.3
29	11.0	.....	14.0	10.3	7.4	7.7	11.6	11.3	5.8	5.6	8.4	5.0
30	11.2	.....	15.0	10.0	7.4	7.5	9.3	9.2	5.6	5.8	7.5	8.3
31	10.5	.....	13.5	.....	7.3	.....	8.5	11.4	.....	5.9	.....	7.7

a For the months of September, October, and November the figures given are an average of four readings daily—6 a. m., 12 m., 6 p. m., and 8 p. m. For the other months the readings are those taken at 6 a. m.

BROAD RIVER AT CARLTON, GEORGIA.

Broad River rises in the northeastern part of Georgia and flows in a southeasterly direction, passing between Elbert and Wilkes counties and emptying into Savannah River 8 miles below Calhoun Falls station. The watershed is a rolling country largely covered with timber. Measurements were begun on Broad River at Carlton on May 27, 1897, this station being established by Max Hall. It is located on the bridge of the Seaboard Air Line, 3 miles east of Carlton, Georgia, and 3 miles above the mouth of the South Fork. The iron bridge is 250 feet long and is approached on each side by wooden trestles. The initial point of soundings is the end of the iron bridge at right bank, upstream. The length of the wire gage is 56.30 feet. Bench mark is top of upstream iron girder under cross-tie at 30 feet from initial point and is 51.00 feet above datum. Zero of gage is 384.5 feet above sea level. The gage was last verified April 25, 1899. The

channel is straight and the flow uninterrupted except by one pier in the center of the river. The banks are rather low and subject to overflow in time of high water. The bed is fairly constant. The observer is S. P. Power, jr., a farmer at Carlton, Georgia. The results of measurements may be found as follows: 1897, Nineteenth Annual Report, Part IV, page 227; 1898, Twentieth Annual Report, Part IV, page 163. The following discharge measurements were made during the year 1899 by Max Hall and assistants:

Measurements of Broad River at Carlton, Georgia.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Sec.-feet.*	1899.	*Feet.*	*Sec.-feet.*
February 28	9.05	8,281	June 28	2.80	1,053
March 1	5.28	3,205	September 27	2.00	514
April 25	3.65	1,841	November 11	2.05	485
May 15	2.60	919	December 21	2.25	591

A measurement of Broad River was made June 28 below the junction of South Broad, 3 miles below the station and 4 miles from Carlton, Georgia, which gave a discharge of 1,135 second-feet. On the same date a measurement of South Broad was made at its mouth, when the discharge was found to be 145 second-feet. On September 22 a second measurement of South Broad was made 4 miles above the mouth above Fork Creek and 1.5 of a mile from Carlton, Georgia, and gave 103 second-feet. On November 11 a third measurement of this latter river was made one-half a mile from mouth, below Fork Creek, and 3 miles from Carlton, giving a discharge of 139 second-feet. The drainage area of South Broad River at its mouth is 215 square miles.

Daily gage height, in feet, of Broad River at Carlton, Georgia, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.10	3.45	5.20	5.80	3.00	2.60	2.30	2.40	3.80	1.90	2.15	2.35
2	2.95	3.00	4.10	4.45	3.00	2.55	2.25	2.35	3.00	1.90	2.10	2.40
3	2.75	3.75	3.80	3.60	2.95	2.50	2.20	2.25	2.50	1.90	2.10	2.30
4	2.70	3.70	3.60	3.65	2.95	2.50	2.20	2.20	2.30	1.90	2.05	2.30
5	2.65	4.30	3.95	3.70	3.00	2.45	2.20	2.20	2.20	2.00	2.05	2.25
6	4.45	7.20	4.20	3.45	3.20	2.40	2.20	2.15	2.15	2.20	2.05	2.20
7	6.45	13.18	3.65	3.60	3.15	2.40	2.25	2.10	2.10	2.15	2.05	2.20
8	6.40	10.60	3.45	4.40	3.00	2.50	2.40	2.10	2.10	4.30	2.05	2.20
9	3.90	5.45	3.40	4.20	2.95	2.60	2.30	2.10	2.10	3.40	2.05	2.20
10	3.30	4.30	3.35	3.60	2.95	2.45	2.40	2.10	2.10	2.50	2.05	2.20
11	3.80	3.75	3.30	3.50	2.90	2.40	2.30	2.15	2.50	2.35	2.05	2.20
12	4.05	3.60	3.30	3.40	2.85	2.60	2.25	2.10	2.10	2.25	2.05	3.40
13	3.70	3.45	3.25	3.30	2.80	3.70	2.20	2.15	2.50	2.20	2.05	3.60
14	3.45	3.35	3.50	3.30	2.80	3.00	2.20	2.05	2.00	2.15	2.05	2.95
15	3.75	3.30	4.40	3.25	2.75	2.40	2.15	2.00	2.00	2.10	2.10	2.50
16	3.50	4.40	13.88	3.25	2.75	2.50	2.10	1.95	1.95	2.10	2.10	2.45
17	3.50	5.05	11.30	3.20	2.70	2.65	2.10	1.90	1.95	2.10	2.05	2.35
18	3.25	4.45	4.70	3.15	2.70	2.65	2.25	1.90	1.95	2.10	2.05	2.30
19	3.10	3.80	4.50	3.25	2.65	2.55	2.15	1.90	1.95	2.10	2.05	2.30
20	3.00	3.50	8.10	3.20	2.65	2.45	2.10	1.90	2.05	2.10	2.05	2.30
21	2.90	3.55	5.20	3.15	2.60	2.40	2.10	2.00	2.00	2.10	2.05	2.25
22	2.85	3.60	4.00	3.10	2.65	2.35	2.05	1.95	2.00	2.05	2.05	2.25
23	2.95	3.50	4.15	3.05	2.70	2.30	2.20	2.00	2.00	2.05	3.65	2.20
24	3.05	3.30	4.55	3.10	2.65	2.30	2.25	1.95	1.95	2.05	3.45	4.40
25	3.00	3.20	3.75	3.20	2.60	2.30	2.15	2.00	1.95	2.05	2.45	4.30
26	2.95	3.15	3.60	3.50	2.60	3.70	2.45	2.05	1.95	2.05	3.60	3.00
27	2.85	15.78	3.50	3.20	2.60	3.00	6.50	3.95	2.00	2.05	3.70	2.60
28	2.80	11.15	3.45	3.15	2.55	2.80	5.30	2.45	1.95	2.05	2.90	2.60
29	2.80	.....	4.20	3.10	2.55	2.80	3.50	2.10	1.95	2.05	2.55	2.60
30	2.75	.....	3.70	3.10	2.50	2.50	2.80	3.50	1.90	2.10	2.40	2.50
31	3.10	.....	5.00	.....	2.70	.....	2.50	4.10	.....	2.15	.....	3.45

OCONEE RIVER AT DUBLIN, GEORGIA.

Oconee River rises in the northern part of Georgia, near Gainesville, on the southern slope of Chattahoochee Ridge, which separates the headwaters of this stream from the tributaries of Chattahoochee River. It flows in a southeasterly direction and joins the Ocmulgee at the southern border of Montgomery County to form the Altamaha. The watershed is for the most part hilly, and is made up of cultivated ground broken by extensive tracts of forest. A station was maintained for a time at Cary, Georgia, immediately below the mouth of Apalachee River. The rating was evidently affected by the dam several miles below, and for this reason the station was abandoned on March 31, 1898. The results of measurements at this station can be found as follows: 1897, Nineteenth Annual Report, Part IV, page 227; 1898, Twentieth Annual Report, Part IV, page 170. A single discharge measurement was made at this station in 1899 on October 19: Gage height, 2.03 feet; discharge, 898 second-feet.

A station was established by the United States Weather Bureau in 1894, at Dublin, Georgia, about 60 miles above the junction of the Oconee with the Ocmulgee, 45 miles below Milledgeville, and 85 miles below the old Cary station. The station was discontinued on April 30, 1897, but was reestablished by the Georgia geological survey, February 11, 1898. Since October 15, 1898, the station has been maintained by the United States Weather Bureau. The station is located about one-half mile east of Dublin, Georgia. The gage is a vertical rod fastened to the lower side of the middle pier of the Wrightsville and Tennille Railroad bridge. The gage is referred to a secondary gage on a hemlock tree on the right bank, 150 feet above, and to a bench mark on the same tree which consists of three large nails 3.00 feet above the zero of the gage, and a second bench mark on another hemlock tree 100 feet above the first, which consists of three large nails 3.00 feet above datum. The channel is straight and without obstructions except the bridge piers. The current is swift, the banks high and not subject to overflows. Discharge measurements are made from the upper side of the county highway iron bridge, which is about 100 yards above the railroad bridge at which the gage is located. The initial point for soundings is the end of the bridge on right bank of the river. Records of measurement may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 77; 1897, Nineteenth Annual Report, Part IV, page 228; 1898, Twentieth Annual Report, Part IV, page 170. The following measurements were made by B. M. Hall and his assistants during 1899:

February 2, gage height, 8.20 feet; discharge, 9,689 second-feet.
April 28, gage height, 8.00 feet; discharge, 9,033 second-feet.
June 8, gage height, 0.80 foot; discharge, 1,937 second-feet.
September 15, gage height, 0.80 foot; discharge, 1,997 second-feet.
September 15, gage height, 0.50 foot; discharge, 1,903 second-feet.
December 14, gage height, 3.90 feet; discharge, 4,028 second-feet.

A discharge measurement was also made on Oconee River at Milledgeville, Georgia, 45 miles above Dublin, on November 21, 1899, when the discharge was found to be 957 second-feet.

Daily gage height, in feet, of Oconee River at Dublin, Georgia, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.80	7.70	11.30	8.30	5.40	1.70	0.50	2.90	2.50	—1.30	—0.40	2.40
2	3.60	8.10	13.80	8.00	4.70	1.80	.60	2.30	2.90	—1.30	— .40	1.10
3	5.20	9.10	16.50	8.50	3.80	1.70	.40	2.00	2.70	—1.30	— .40	2.00
4	5.80	9.90	17.00	9.00	3.70	1.50	.20	1.70	2.10	—1.30	— .50	1.90
5	5.00	10.70	16.90	9.80	3.50	1.40	.10	1.50	1.50	— .80	— .50	1.70
6	4.70	12.70	16.20	9.50	4.10	1.20	.00	.90	1.10	.50	— .50	1.60
7	5.00	13.10	14.50	9.00	5.00	1.00	.20	.80	.80	2.40	— .50	1.30
8	7.80	15.00	12.70	8.60	4.80	.80	.40	.70	.30	5.10	— .60	1.10
9	8.60	20.10	11.00	8.00	4.40	.70	.00	.20	.20	7.20	— .60	.90
10	10.40	22.50	9.80	7.80	3.60	.60	—.10	—.30	.10	8.10	— .70	.70
11	12.20	21.70	8.60	7.50	3.00	.50	—.10	—.40	.00	8.60	— .70	.50
12	14.10	18.90	7.60	7.00	2.70	.40	—.20	—.20	.10	6.80	— .70	1.20
13	14.40	17.50	7.00	6.40	2.70	.30	—.30	—.10	.70	4.10	— .80	2.60
14	15.30	16.80	6.80	5.60	2.40	.30	—.40	—.10	1.50	1.70	— .80	3.30
15	14.80	15.50	6.70	5.20	2.30	.90	—.40	—.20	.80	1.10	— .10	4.10
16	14.50	13.70	7.30	5.00	2.10	1.20	—.40	—.30	.10	.60	.70	3.20
17	14.30	12.40	7.90	4.90	2.00	.70	—.50	—.50	— .30	.50	.10	2.50
18	13.70	12.50	8.30	4.80	1.90	.30	—.60	—.60	— .40	.50	.80	1.90
19	13.30	12.70	9.20	5.30	1.80	.30	—.60	—.70	— .50	.50	.10	1.50
20	13.10	13.30	10.10	5.80	1.70	.60	—.60	—.80	— .60	.40	— .20	1.30
21	12.80	13.60	10.90	5.60	1.60	.90	—.70	—.80	— .70	.40	— .30	1.20
22	12.60	13.00	12.60	5.50	1.50	.50	—.70	—.90	— .80	.20	— .40	1.20
23	11.30	12.40	14.20	5.20	1.50	.30	—.70	—.70	— .90	.00	— .30	1.40
24	8.30	10.80	13.40	5.00	1.80	.20	—.80	—.30	— .90	— .10	.10	1.40
25	7.80	9.80	11.90	4.80	2.10	.20	—.80	—.20	—1.00	— .30	1.50	2.30
26	7.30	9.00	10.00	5.90	1.80	.00	.30	2.50	—1.00	— .40	1.30	5.20
27	7.10	9.70	9.60	7.40	1.70	—.10	.70	3.00	—1.10	— .50	2.10	5.60
28	6.80	9.60	8.90	8.00	1.60	—.20	.90	3.00	—1.10	— .60	3.20	4.60
29	7.00	.....	8.30	7.20	1.60	—.20	1.80	5.10	—1.10	— .70	4.40	3.90
30	7.40	.....	8.10	6.10	1.60	.40	4.70	4.50	—1.20	— .70	3.30	2.80
31	7.60	.....	8.00	.....	1.60	.....	5.00	2.90	.....	— .30	.....	2.60

YELLOW RIVER AT ALMON, GEORGIA.

This river is an important tributary of the Ocmulgee. Its headwaters are in Gwinnett County, only a short distance from Chattahoochee River. About one-third of the watershed is under cultivation, the ground being well terraced on the hillsides. The drainage area is entirely mapped on the Monroe, Gainesville, Suwanee, and Atlanta atlas sheets of the United States Geological Survey. There are a number of falls along the river capable of development for water power. A gaging station was established at Almon, 3 miles west of Covington, Georgia, September 12, 1897. It was at the low wagon bridge crossing the stream, 600 feet below the Georgia Railroad bridge. Results of measurements at this station may be found as follows: 1897, Nineteenth Annual Report, Part IV, page 230; 1898, Twentieth Annual Report, Part IV, page 170. No current-meter measurements were made during 1898, nor were the gage heights recorded. An attempt was made, however, to ascertain the fluctuations of discharge for comparison with the observations made at Macon. A rating table published on page 229 of the Nineteenth Annual Report, Part IV, was constructed from discharge measurements made during the autumn of 1897. A rating table for 1898 is published in Water-Supply Paper No. 27, of the United States Geo-

logical Survey. The application of such a table involves the assumption that the fluctuations at Almon are coincident with those at Macon, and as it is of uncertain accuracy, the old station at Almon has been abandoned and a new station was established May 9, 1899, by B. M. Hall, about 1 mile above the old station. It is intended to maintain this station for six months or more, in order to study the water powers above and below. The gage rod is fastened to a small tree on the left bank below the bridge, and referred to a bench mark on top of the downstream end of floor beam, 90 feet from the initial point of soundings, which is the right-bank end of the hand rail on the downstream side of the bridge. The elevation of bench mark is 20.81 feet above datum. The gage was verified May 9, 1899. The channel is straight, the current swift and not influenced by obstructions except at very low water, when the current is entirely under the west half of the bridge. The banks are high but are overflowed at the highest waters. The bed is rocky and constant. The following measurements were made by B. M. Hall and assistants during 1899:

May 3, gage height 2.97 feet; discharge 481 second-feet.
May 9, gage height 3.16 feet; discharge 561 second-feet.
May 16, gage height 2.30 feet; discharge 364 second-feet.
June 6, gage height 1.80 feet; discharge 235 second-feet.
June 27, gage height 2.42 feet; discharge 427 second-feet.
August 7, gage height 1.40 feet; discharge 218 second-feet.
October 19, gage height 1.70 feet; discharge 200 second-feet.

Daily gage height, in feet, of Yellow River at Almon, Georgia, for 1899.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	2.40	1.60	1.90	2.10	1.20	1.60	2.00
2	.....	2.10	1.50	1.80	2.00	1.20	1.60	2.70
3	.....	2.00	1.40	1.70	1.80	1.20	1.50	2.50
4	.....	1.90	1.30	1.60	1.60	1.20	1.50	2.30
5	.....	1.80	1.40	1.60	1.50	1.70	1.50	2.00
6	.....	1.80	1.50	1.40	1.50	2.00	1.50	1.90
7	.....	1.70	1.80	1.40	1.50	2.50	1.50	1.90
8	.....	1.70	1.60	1.40	1.50	4.00	1.50	1.90
9	3.20	1.70	1.80	1.30	1.40	2.80	1.50	1.90
10	2.80	1.70	1.60	1.30	1.40	2.20	1.50	1.90
11	2.80	1.70	1.40	1.30	2.50	1.80	1.50	1.90
12	2.70	2.00	1.40	1.30	2.00	1.80	1.50	4.00
13	2.70	2.50	1.30	1.20	1.70	1.80	1.50	3.00
14	2.50	2.10	1.30	1.20	1.50	1.80	1.50	2.50
15	2.50	1.90	1.20	1.20	1.50	1.70	1.50	2.30
16	2.50	1.80	1.20	1.10	1.40	1.70	1.60	2.00
17	2.30	1.80	1.20	1.10	1.40	1.70	1.50	2.00
18	2.10	1.80	1.80	1.00	1.40	1.70	1.50	2.00
19	2.30	1.70	1.40	1.00	1.30	1.70	1.50	2.00
20	2.10	1.60	1.40	1.00	1.30	2.00	1.50	2.00
21	2.00	1.50	1.60	1.00	1.30	1.90	1.50	2.00
22	2.30	1.50	1.80	1.00	1.30	1.70	1.50	2.00
23	2.80	1.50	2.00	1.00	1.30	1.50	2.20	2.00
24	2.50	1.40	1.40	1.00	1.20	1.50	2.20	5.50
25	2.20	1.40	1.60	1.00	1.20	1.50	1.90	4.60
26	2.00	3.20	2.40	3.60	1.20	1.50	4.50	3.40
27	2.00	2.60	5.80	3.00	1.20	1.50	4.00	2.50
28	2.00	2.00	5.00	2.80	1.20	1.50	3.20	2.50
29	1.90	2.00	3.70	2.70	1.20	1.60	2.50	2.50
30	1.80	1.80	2.80	2.50	1.20	1.70	2.00	2.50
31	3.30	.....	2.00	2.30	.....	1.70	.....	2.30

TOWALIGA RIVER AT JULIETTE, GEORGIA.

The drainage basin of this stream occupies a small area in central Georgia, its headwater tributary adjoining those of Flint River on the west, and small creeks draining into the Ocmulgee on the east. The river is a tributary of Ocmulgee River, entering it 25 miles above Macon. The area drained is a rolling country and extensively cultivated. A gaging station was established by B. M. Hall near its mouth, at the Southern Railway bridge, 2½ miles north of Juliette, Georgia, on May 5, 1899, but observations of gage heights were not started until November 2. The rod is 1 by 4 inches and 7 feet long, nailed to the timber crib at base of left bank pier of the iron single-span bridge. Bench mark No. 1 is at top of downstream iron girder under cross-ties at 40 feet from left end of bridge, and is 37.00 feet above gage datum. Bench mark No. 2, top of rail at same point, gage height 38.80 feet. At low stages measurements are made at the wagon bridge a half mile above the railroad bridge. Thomas Pittman, a farmer living one-half mile from the bridge, is the observer. His address is Berner, Georgia. The following measurements were made by B. M. Hall and assistants in 1899:

May 5, gage height 3.15 feet; discharge 581 second-feet.
May 17, gage height 1.80 feet; discharge 255 second-feet.
November 2, gage height 1.20 feet; discharge 167 second-feet.
November 2, gage height 1.20 feet; discharge 163 second-feet.
December 16, gage height 1.90 feet; discharge 184 second-feet.

Daily gage height, in feet, of Towaliga River at Juliette, Georgia, for 1899.

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1	.....	1.70	9	1.20	1.60	17	1.60	1.80	25	1.20	3.80
2	1.20	1.65	10	1.10	1.55	18	1.30	1.70	26	3.35	2.50
3	1.20	1.65	11	1.20	1.50	19	1.30	1.70	27	3.20	2.10
4	1.10	1.75	12	1.10	3.70	20	1.20	1.70	28	2.20	1.10
5	1.10	1.75	13	1.10	3.60	21	1.30	1.70	29	1.95	2.00
6	1.10	1.65	14	1.10	2.50	22	1.20	1.50	30	1.80	1.90
7	1.10	1.55	15	1.10	2.00	23	1.30	1.60	31	.....	1.90
8	1.10	1.50	16	1.70	1.90	24	1.20	4.00			

OCMULGEE RIVER AT MACON, GEORGIA.

The Ocmulgee River rises in the north-central part of Georgia and flows in a southeasterly direction, joining the Oconee south of Mount Vernon to form the Altamaha River, which empties into the Atlantic Ocean. The drainage area has the same general features as that of the Oconee. A station was established by the United States Weather Bureau January 21, 1893, and measurements were begun by the United States Geological Survey in 1895. This station is described in the Eighteenth Annual Report, Part IV, page 79. The wire gage on the Macon, Dublin and Savannah Railroad bridge having been twice stolen in the spring of 1897, the observations were taken on the Weather Bureau gage referred to the same data, which is a vertical

rod bolted to the stone pier of the Central Railroad bridge. Bench mark, top of track on Central Railroad bridge, is 54.85 feet above zero of gage. Measurements of discharge are made from the wagon bridge, a short distance above. The channel is straight and without obstructions except two bridge piers. The current is over 1 foot per second at low water; the banks high and not subject to overflow. The bed of the river is soft and changeable. W. T. Bass, a clerk in a store near the gage, was observer for the United States Geological Survey and the Georgia geological survey until June 1, 1899, when the station was resumed by the United States Weather Bureau, in charge of Mr. T. S. Collins, observer. Records of measurement may be found as follows: 1893–96, Eighteenth Annual Report, Part IV, page 82; 1897, Nineteenth Annual Report, Part IV, page 232; 1898, Twentieth Annual Report, Part IV, page 171. The following measurements were made by B. M. Hall and his assistants during 1899:

Measurements of Ocmulgee River at Macon, Georgia.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Sec.-feet.*	1899.	*Feet.*	*Sec.-feet.*
February 1	9.72	6,302	June 21	1.22	1,009
February 3	13.75	14,954	August 2	1.98	1,345
February 3	13.75	14,781	September 14	1.70	1,314
February 3	12.81	12,687	September 16	.80	793
April 14	4.59	2,587	October 21	2.30	1,814
April 29	5.00	3,094	December 13	4.50	3,009
June 7	1.60	1,015	December 15	2.50	1,540
June 9	1.48	983			

Daily gage height, in feet, of Ocmulgee River at Macon, Georgia, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.42	9.60	14.72	11.30	4.05	4.40	1.50	2.50	2.60	0.30	0.80	1.70
2	6.60	8.41	11.14	8.71	3.80	2.80	1.50	2.10	1.80	.30	.60	1.50
3	5.96	13.70	9.11	7.97	3.60	2.60	1.20	1.40	2.00	.30	.60	1.20
4	5.21	11.98	8.32	7.86	3.50	2.60	.90	1.40	1.80	.40	.50	2.10
5	3.70	9.94	8.11	8.11	3.45	1.90	.90	1.20	1.80	.50	.50	1.90
6	4.12	10.80	7.62	7.85	3.10	1.80	1.00	1.00	1.10	2.30	.50	1.50
7	15.20	15.83	6.81	6.89	6.72	1.60	1.10	.80	.70	2.00	.40	1.30
8	12.65	13.42	6.72	6.50	5.30	1.60	1.50	.70	.70	10.00	.40	1.10
9	10.21	12.13	6.40	5.97	3.80	1.60	2.00	.60	.50	6.40	.40	1.10
10	9.23	10.80	6.11	5.63	3.55	1.40	1.30	.50	.40	3.20	.40	1.00
11	12.14	9.78	5.81	5.42	3.28	1.60	1.10	2.10	2.20	2.20	.40	1.10
12	11.87	8.21	5.74	5.01	3.10	1.50	.90	1.00	2.50	1.80	.50	3.70
13	9.38	7.60	5.69	4.71	2.96	2.30	.80	1.20	2.20	1.30	.50	4.70
14	8.96	7.13	5.58	4.58	2.90	2.90	.80	.80	1.70	1.00	.50	3.90
15	8.21	6.10	5.51	4.40	2.82	2.20	.70	.70	.90	1.00	.80	2.60
16	9.67	12.30	8.51	5.01	2.69	1.70	.60	.70	.60	.90	.70	2.00
17	12.91	11.98	7.21	4.42	2.52	1.50	.60	.60	.60	.80	.70	1.80
18	10.87	11.12	9.38	4.33	2.45	2.30	.50	.60	.50	.80	.70	1.50
19	9.34	9.76	12.94	10.38	2.33	1.40	.70	.50	.50	.80	.60	1.40
20	5.91	8.32	10.72	7.82	2.20	1.30	.90	.40	.40	2.00	.60	1.40
21	5.11	8.27	9.42	5.52	2.18	1.30	1.00	.40	.30	2.80	.60	1.30
22	5.42	8.16	8.11	4.72	2.48	1.20	.80	a.00	.30	3.20	.50	1.30
23	5.10	8.10	6.42	4.61	3.67	1.00	1.30	3.30	.30	2.40	.60	1.40
24	5.37	7.18	8.66	5.48	3.35	.90	3.20	3.10	.20	1.60	1.00	6.40
25	5.31	6.28	8.85	11.87	3.01	.90	2.00	2.10	.20	1.20	1.40	5.90
26	5.01	6.13	6.93	12.41	2.40	1.20	2.00	1.20	.40	1.00	4.40	5.20
27	4.71	12.13	6.01	8.22	2.18	3.20	2.30	.80	.40	.80	5.30	3.50
28	4.69	14.91	7.87	5.84	2.12	3.20	4.30	3.00	.40	.70	4.20	2.60
29	5.08	.....	7.30	5.16	2.06	1.60	5.10	2.30	.30	1.40	3.10	2.30
30	4.90	.....	6.91	4.71	2.06	1.70	4.20	1.80	.30	1.00	2.00	2.10
31	5.07	.....	6.28	.....	2.15	.....	3.20	2.40	.....	1.10	.....	1.60

a Mud around gage.

FLINT RIVER, AT ALBANY, GEORGIA.

This river, known to the Indians as the "Thronateeska," rises in the west-central part of Georgia and flowing in a southerly direction cuts through Pine Mountain Range just below Molena. It joins the Chattahoochee to form Apalachicola River. Its drainage area is hilly and rolling on the headwaters and level at the lower end. It is largely cultivated, but most of the ground is well terraced. A station was established at Molena, Georgia, June 7, 1897. Measurements were made during 1897 and 1898, and a rating table constructed by Prof. B. M. Hall. The alternate accumulation and washing out of sediment in an eddy one-half mile below so affected the gage height that it has not been possible to establish a definite relation between them and the discharge measurements, and the station was discontinued June 2, 1898. Records of measurement made at Molena may be found as follows: 1897, Eighteenth Annual Report, Part IV, page 234; 1898, Nineteenth Annual Report, Part IV, page 233. Two measurements were made in 1899 at the Macon and Birmingham bridge, near Woodbury, Georgia, 5 miles below the old Molena station. The gage heights are assumed, based on permanent bench marks. First measurement, January 29, gage height, 0.80 foot; discharge, 590 second-feet. Second measurement, August 29, gage height, 0.57 foot; discharge, 461 second-feet.

The United States Weather Bureau has a gage rod at Reynolds, 80 miles above Albany. It was erected in 1893 by the United States Engineer Corps. The rod is attached to the middle pier of the railroad bridge, 3 miles east of the town. The drainage area above Reynolds is reported to be 2,000 square miles.

A second station has been maintained at Albany, Georgia, by the United States Weather Bureau. The drainage area at this point is, approximately, 5,000 square miles. Mr. J. B. Marbury, the local forecast official at Atlanta, Georgia, furnishes the following information:

The river gage is in two sections. the long section, from 10 to 36 feet, is nailed in two segments to the south face downstream side of the west pier, on the right or Albany side of the river; the short section is nailed to a cypress tree 120 feet down the river from the pier. The top of the pier foundation sill is 8.1 feet above low water. A second gage, reading from zero to 21 feet, is nailed to a cypress tree on the left bank of the river about 100 feet downstream from the point where the south side of Commerce street, if extended, would cross the river. The first bench mark is the top of the wide marble foundation stone of the African Methodist Episcopal Church, corner of Washington and State streets, Albany, Georgia. It is 49.5 feet above zero of gage. A second bench mark is the top of the sill of the old wharf at the foot of Broad street. It is 3 feet above low water. The observer is John E. Clark. No measurements of discharge were made in 1899 at this station.

Daily gage height, in feet, of Flint River at Albany, Georgia, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	6.70	8.30	14.30	8.30	5.40	2.40	0.50	4.30	2.50	0.40	0.60	4.10
2	6.50	8.70	14.30	7.80	4.80	2.40	.60	4.70	2.10	.10	.70	4.30
3	6.40	8.90	15.10	7.00	4.40	2.20	.40	4.90	2.00	.20	.70	4.50
4	6.40	9.20	15.90	6.70	4.20	2.00	.20	4.90	2.30	.20	.70	4.50
5	7.30	9.60	15.90	6.40	4.10	2.00	.10	4.10	2.20	.20	.70	4.50
6	9.20	10.80	14.30	6.90	4.00	2.00	.00	3.90	2.00	.30	.70	4.20
7	10.00	11.60	13.00	7.50	3.80	2.00	.20	3.50	2.00	.90	.60	3.90
8	10.00	12.30	12.10	8.00	3.30	1.90	.40	3.30	2.00	1.30	.60	3.80
9	9.50	13.80	11.80	7.40	3.00	1.70	.00	3.00	2.10	1.60	.60	3.70
10	11.60	14.60	11.50	7.80	2.80	1.30	—.10	2.60	2.10	1.90	.50	3.50
11	13.50	15.90	10.90	8.00	2.60	1.20	—.10	2.60	2.00	2.40	.50	3.30
12	16.70	17.30	9.40	7.40	2.40	1.20	—.20	2.30	2.10	2.40	.40	3.70
13	16.80	18.20	8.30	6.90	2.00	1.20	—.30	2.20	2.20	2.40	.20	3.90
14	17.00	19.90	8.00	6.50	1.80	1.20	—.40	1.80	2.20	2.70	.30	4.10
15	17.00	21.80	7.80	5.00	1.70	.90	—.30	1.50	2.30	2.80	.60	4.30
16	17.50	19.00	8.30	5.00	1.50	.70	—.40	1.20	2.40	2.80	.70	4.30
17	18.00	17.60	8.90	5.00	1.30	.50	—.50	1.00	2.50	2.90	.80	4.00
18	18.80	16.90	9.60	5.20	1.20	.50	—.60	1.00	2.20	3.00	.80	3.80
19	17.30	15.20	10.40	5.30	1.00	.40	—.60	1.00	2.30	3.00	.90	3.60
20	16.90	14.60	11.30	5.50	.90	.40	—.60	.80	1.80	2.90	.80	3.30
21	15.30	14.30	12.80	5.50	.90	.40	—.70	.70	1.60	3.20	.80	3.10
22	14.10	13.90	11.90	5.50	.90	.30	—.70	.70	1.50	3.40	.90	3.40
23	12.30	13.20	11.60	5.50	1.00	.30	—.70	.90	1.20	3.20	.90	3.50
24	11.00	13.00	11.50	5.90	2.30	.60	—.80	1.10	1.10	2.70	1.00	3.50
25	10.20	12.00	11.30	6.70	3.80	.80	—.80	1.60	1.20	2.70	1.20	3.70
26	9.40	11.30	10.60	6.90	4.30	.90	—.30	.50	1.30	2.50	1.50	3.90
27	8.70	10.20	10.00	7.00	5.40	.90	—.70	.30	1.80	1.70	1.60	4.00
28	8.20	12.30	9.40	6.30	4.30	.80	—.90	.30	1.90	1.30	1.70	4.20
29	7.90	.....	9.20	6.00	3.80	.80	1.80	.30	1.90	.90	2.20	2.50
30	7.90	.....	8.90	5.80	3.00	1.30	1.70	.20	1.90	.70	2.60	4.90
31	7.90	.....	9.10	.....	2.50	.....	5.00	.20	.....	.50	.....	5.90

CHATTAHOOCHEE RIVER AT OAKDALE, GEORGIA.

This river rises in the northeastern part of Georgia and flows in a southwesterly direction to the boundary line between Georgia and Alabama, when it turns to the southward and forms the dividing line between these States to the southern border of Georgia, where it joins Flint River to form the Apalachicola. Its watershed above the mouth of Chestatee River is mountainous and over 80 per cent in oak forests; from thence to West Point, Georgia, it is narrow and hilly and about 50 per cent is under cultivation. From West Point to Columbus, Georgia, is through a rocky, mountainous, well-wooded country. Below Columbus, Georgia, the river is navigable, but the country is hilly, consisting of extensive high plains traversed by deep narrow valleys. The drainage area above Oakdale is entirely mapped on the following atlas sheets: Marietta, Walhalla, Dahlonega, Ellijay, Suwanee, Gainesville, and Atlanta. A large number of important water-power privileges occur on the tributaries and on the main river. The most important fall occurs near Columbus, where the river descends 120 feet in 4 miles. A fall of 362 feet from West Point to Columbus, a distance of 34 miles, occurs in a number of shoals, separated by stretches of comparatively quiet water. Elaborate surveys of shoals near Atlanta, Georgia—Vining Shoal, 32 feet, and Bull Sluice, 50 feet—have been made by companies with the object of development and electric transmission to Atlanta. Two gaging stations are maintained on the Chattahoochee River, one at Oakdale, about 8 miles

northwest of Atlanta, and the other at West Point, Georgia, where the Chattahoochee River reaches the Alabama State line. The station was established at Oakdale by Cyrus C. Babb on October 17, 1895. It is described in the Eighteenth Annual Report, Part IV, page 85. It was located at the Southern Railway bridge, 1 mile above the mouth of Proctor Creek.

On July 30, 1896, the location of the station was changed to Mason & Turners Ferry, 1 mile below Oakdale. The gage at this point, known as the "Oakdale lower gage," is nailed to a tree on the right bank, 100 feet below the ferry, and set 1 foot lower than the gage at the Southern Railway bridge. On June 1, 1899, the lower gage was discontinued and the upper gage resumed and adopted by the United States Weather Bureau, the United States Geological Survey still receiving the records and making current-meter discharge measurements at that point. The gage recently put in and now used is set on the same datum as the old wire gage of the United States Geological Survey, established at that point by Mr. Babb in 1895, and above referred to, but is a vertical, timber, rod, 3.25 inches by 6 inches by 28 feet, bolted with five iron bolts to the east side of the center pier of the Southern Railway bridge. It is well painted and is graduated into feet with brass figures and into tenths with copper nails from −1.5 feet to +26.5 feet, making its total length 28 feet. Its zero point is 753.5 feet above sea level. Bench mark No. 1 is a railroad spike in corner of pier, right bank, 12.39 feet above datum of gage. Bench mark No. 2 is top of downstream iron girder under cross-ties, 23 feet from west end of bridge, and is 54.75 feet above gage datum. The flow is obstructed by rafts, which have to be cleared from the channel occasionally. The channel is straight and the current swift. The banks are subject to overflow. The bed of the stream is constant and the results obtained fairly good. All discharge measurements made in 1899 are referred to the upper gage at the railroad bridge. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 85; 1897, Nineteenth Annual Report, Part IV, page 236; 1898, Twentieth Annual Report, Part IV, page 182. The following measurements were made during 1899 by B. M. Hall and assistants:

Measurements of Chattahoochee River at Oakdale, Georgia.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Sec.-feet.*	1899.	*Feet.*	*Sec.-feet.*
March 11	4.35	4,397	September 9	1.32	1,452
May 1	3.80	3,452	October 6	.67	1,150
May 26	2.36	2,678	October 17	.54	1,063
June 14	3.92	4,788	November 18	.42	988

A number of miscellaneous discharge measurements were made on tributaries of Chattahoochee River by B. M. Hall and his assist-

ants during 1899. They are as follows, arranged in geographic order from the headstream down: Three measurements of Soquee River were made at Porter Mills, near Clarksville, Georgia. The first, on May 29, showed a discharge of 342 second-feet; the second, on June 7, gave a discharge of 239 second-feet; the third, on June 10, gave a discharge of 231 second-feet. The measurement of Hazel Creek, below the ford between Demorest and Porter Mills, on June 10, showed a discharge of 63 second-feet. Two measurements were made on Chattahoochee River at Shallow Ford bridge, near Gainesville, Georgia, 5 miles above the mouth of Chestatee River. The first, on June 22, at a gage height of 1.30 feet, showed a discharge of 933 second-feet; the second, on October 10, at a gage height of 0.95 foot, showed a discharge of 613 second-feet. Chestatee River at Newbridge post-office, Georgia, was discharging 354 second-feet on July 19. Chattahoochee River at Barkers Ferry, near Buford, Georgia, was carrying 782 second-feet on November 17. Sweetwater Creek enters the Chattahoochee 10 miles below Oakdale, Georgia. Three measurements of its discharge were made at the Strickland bridge near Austell. The first measurement, on April 19, gage height, 3.20, showed a discharge of 402 second-feet; the second, on June 24, gage height, 1.1 feet, gave a discharge of 242 second-feet. The third measurement, on October 24, gave a discharge of 108 second-feet. The three following measurements were made of Chattahoochee River, between Oakdale and West Point: October 3, at Moodys bridge, on the Owensbyville wagon road, at a gage height of 0.0 feet, the discharge was 1,165 second-feet; on October 4 the river at Franklin, Georgia, about 40 miles above West Point, at a gage height of —0.70 foot, showed a discharge of 1,164 second-feet; on November 4 this river at McGees bridge, about 20 miles above West Point, Georgia, at a gage height of 0.40 foot, was carrying 1,670 second-feet.

Yellow Jacket Creek, at its mouth just above McGees bridge, was discharging 77 second-feet on November 4.

Daily gage height, in feet, of Chattahoochee River at Oakdale, Georgia, for 1899.

LOWER GAGE AT MASON & TURNER'S FERRY. (a)

Day.	Jan.	Feb.	Mar.	Apr.	May.	Day.	Jan.	Feb.	Mar.	Apr.	May.
1	4.25	5.10	9.80	13.00	4.70	17	4.75	7.25	24.25	5.25	3.60
2	4.75	4.50	6.85	7.75	4.45	18	4.50	6.10	11.00	4.95	3.50
3	3.60	5.80	6.17	6.50	4.40	19	4.10	5.60	10.50	5.00	3.55
4	3.40	4.90	5.90	7.75	4.35	20	3.90	4.90	15.00	4.95	3.50
5	3.10	6.50	8.10	6.50	4.50	21	3.75	5.25	8.75	4.85	3.45
6	3.75	10.00	8.50	5.90	5.10	22	3.60	5.20	7.25	4.65	5.50
7	6.75	16.00	6.40	6.50	4.60	23	3.90	5.00	9.50	4.75	3.60
8	6.10	21.50	5.90	7.75	4.35	24	4.25	4.90	9.00	4.95	3.50
9	5.25	13.40	5.50	7.50	4.25	25	4.10	4.60	6.50	7.25	3.35
10	4.70	9.50	5.25	7.10	4.10	26	4.25	10.23	7.10	8.00	3.25
11	6.30	6.40	5.10	6.80	4.00	27	3.70	22.13	6.20	6.25	3.15
12	4.75	5.50	5.00	5.75	3.95	28	3.45	18.88	6.10	5.25	3.10
13	4.25	4.90	4.95	5.25	3.90	29	3.25	.....	7.90	5.00	3.20
14	4.50	4.10	6.25	5.20	3.85	30	3.50	.....	6.45	4.80	6.10
15	5.50	4.60	10.00	5.10	3.80	31	4.65	.....	12.30	.....	3.40
16	4.90	5.60	21.50	5.00	3.70						

a Discontinued May 31.

UPPER GAGE AT SOUTHERN RAILWAY BRIDGE.

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1..	2.45	1.50	1.70	4.60	0.40	0.60	1.30	17...	2.05	0.80	0.60	0.50	0.50	0.60	1.60
2..	2.40	1.40	1.40	2.70	.10	.50	1.80	18...	2.05	1.09	.60	.30	.60	.50	1.30
3..	2.30	1.35	1.20	2.10	.10	.50	1.50	19...	2.00	1.30	.50	.40	.60	.50	1.10
4..	2.10	1.25	1.10	1.90	.10	.50	1.40	20...	1.90	1.00	.40	.40	.80	.40	1.20
5..	2.05	1.20	1.10	1.60	.40	.50	1.10	21...	1.75	1.35	.40	.40	.90	.40	1.10
6..	2.00	1.40	1.00	1.00	.60	.40	.90	22...	1.70	3.80	.40	.40	.70	.90	1.10
7..	2.00	1.40	.90	.90	1.60	.40	.80	23...	1.55	2.30	.30	.30	.60	2.00	3.40
8..	2.05	1.40	.80	.80	1.50	.40	.80	24...	1.55	1.90	.20	.30	.50	2.40	5.50
9..	2.05	1.40	.70	.70	2.00	.40	.80	25...	1.80	.80	.10	.30	.50	1.70	4.60
10..	2.10	1.30	.60	.70	1.20	.40	.80	26...	2.05	2.10	.20	.30	.40	3.00	3.40
11..	2.15	1.30	.60	3.00	.90	.40	.70	27...	2.20	2.10	5.20	.20	.50	2.80	2.40
12..	2.75	1.10	.50	1.10	.70	.70	2.20	28...	2.00	5.90	3.40	.20	.50	2.70	2.00
13..	4.80	1.10	.50	.90	.70	.50	6.40	29...	1.80	3.40	1.40	.20	.90	2.10	2.10
14..	4.00	.90	.50	.80	.70	.50	3.10	30...	1.60	3.30	3.20	.20	.70	1.80	1.80
15..	2.90	.80	.50	.70	.60	.50	2.40	31...	.....	3.20	2.80	.....	.60	.....	1.70
16..	2.25	.80	.60	.60	.50	.60	1.80								

CHATTAHOOCHEE RIVER AT WEST POINT, GEORGIA.

This station was established July 30, 1896, by Max Hall, and is at the highway bridge in West Point, Georgia, about 1,200 feet above the railroad passenger station. A wire gage is suspended from the bridge and referred to four bench marks. First bench mark, downstream end, top of first iron-floor beam from the west bank pier of highway bridge, elevation 24.01 feet above datum; second bench mark, downstream end, top of second iron-floor beam from west bank pier of the highway bridge, elevation 24.19 feet above datum; third bench mark, top of second stone pier, Atlanta and West Point Railroad bridge, 1,000 feet upstream, elevation 24.65 feet; fourth bench mark, notch in large oak tree, east bank of river, 100 feet above wagon bridge, elevation 19.26 feet. The length of the wire gage is 33.46 feet. The gage was last verified March 14, 1899. The channel is straight and without obstructions, except from the piers of the bridge. The flow is sluggish in low stages of water. The banks overflow at high water, but all ordinary stages of water pass through the main channel. The bed of the stream is fairly constant. The observer is C. P. Jennings, a clerk in the Atlanta and West Point freight depot. He is paid by the United States Weather Bureau. The results of measurements at West Point may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 92; 1897, Nineteenth Annual Report, Part IV, page 239; 1898, Twentieth Annual Report, Part IV, page 183. The following measurements were made by B. M. Hall and his assistants during 1899:

March 14, gage height, 5.30 feet; discharge, 8,726 second-feet.
April 24, gage height, 4.72 feet; discharge, 7,144 second-feet.
May 13, gage height, 3.80 feet; discharge, 4,828 second-feet.
June 26, gage height, 3.06 feet; discharge, 3,234 second-feet.
September 12, gage height, 3.10 feet; discharge, 3,689 second-feet.
October 18, gage height, 2.07 feet; discharge, 2,088 second-feet.
December 16, gage height, 3.49 feet; discharge, 4,111 second-feet.

Daily gage height, in feet, of Chattahoochee River at West Point, Georgia, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.30	4.50	14.50	10.00	4.30	3.60	3.00	2.50	2.40	1.10	2.10	4.40
2	4.35	4.65	12.70	7.70	4.20	3.30	2.80	2.30	2.00	1.30	2.10	4.30
3	4.20	10.20	6.50	7.00	4.10	3.20	2.70	2.80	2.90	1.30	1.90	3.40
4	4.10	8.30	5.80	7.15	3.90	3.10	2.50	2.80	2.40	1.10	1.90	3.40
5	4.00	7.20	6.40	6.70	3.80	3.00	2.40	2.70	2.10	1.40	1.90	3.40
6	4.00	5.80	7.00	6.40	3.75	3.00	2.40	2.80	3.00	1.50	1.90	3.20
7	5.50	9.10	6.10	6.90	3.75	2.90	2.40	2.80	2.90	1.80	1.90	3.10
8	5.75	13.30	5.60	7.30	3.70	2.80	2.80	2.70	2.00	2.40	1.90	3.10
9	5.50	13.00	5.20	6.80	3.80	2.80	2.90	2.40	1.90	2.70	1.90	2.90
10	5.60	9.05	5.00	6.30	4.00	3.00	3.00	2.30	2.90	2.60	1.90	2.60
11	7.00	6.30	4.90	6.00	3.80	3.10	3.20	2.10	2.50	2.30	1.90	2.40
12	8.80	5.90	4.85	5.40	3.70	3.20	2.50	2.20	2.10	2.30	1.90	3.50
13	5.90	5.20	4.90	5.15	3.65	3.80	2.30	2.30	2.40	2.10	1.90	4.00
14	5.40	4.75	5.00	5.10	3.65	4.00	2.30	2.40	2.60	1.90	1.90	4.60
15	6.00	5.00	5.10	5.05	3.65	4.10	2.30	2.00	2.80	2.40	2.10	4.10
16	5.20	5.20	10.50	5.00	3.60	3.60	2.10	2.50	2.40	2.50	2.20	3.60
17	5.00	5.10	12.30	4.95	3.60	3.10	2.30	3.00	1.60	2.30	2.20	3.10
18	4.90	4.60	13.50	4.90	3.50	3.00	2.30	3.20	1.60	2.30	2.10	3.00
19	4.75	4.30	12.10	4.80	3.20	2.90	2.50	2.90	1.60	2.60	2.10	2.80
20	4.50	4.00	10.75	4.60	3.10	2.80	2.70	2.40	1.50	2.90	2.10	2.80
21	4.20	3.75	8.20	4.45	3.10	2.80	3.00	2.60	1.70	3.30	2.10	2.80
22	4.10	3.60	7.50	4.60	3.05	2.60	3.60	2.90	1.90	2.40	1.90	2.80
23	4.05	3.60	6.90	4.65	3.05	2.50	4.20	3.00	2.30	2.40	2.00	3.20
24	3.90	3.50	7.20	4.70	4.80	2.70	4.70	3.20	1.10	2.30	2.20	6.00
25	3.60	3.50	7.00	4.80	4.10	2.90	3.60	3.50	1.20	2.50	3.00	5.70
26	3.60	3.50	6.50	5.60	3.80	3.40	3.00	2.00	1.20	2.10	3.10	5.60
27	3.50	10.70	6.20	6.05	3.10	3.50	3.20	2.50	1.20	2.00	3.40	4.10
28	3.65	15.20	6.15	5.10	3.40	3.20	5.90	3.10	1.30	2.10	3.20	3.60
29	3.75	.....	6.80	5.00	3.30	3.00	3.30	3.60	1.80	2.10	3.50	3.40
30	4.00	.....	6.30	4.70	3.25	3.20	2.90	2.90	1.90	2.20	4.20	3.30
31	4.75	.....	7.15	.....	4.00	.....	2.70	2.10	.....	2.10	.....	3.20

A station has been maintained by the United States Weather Bureau at Eufaula, Alabama, 80 miles below West Point. The rod is attached to the west side of brick pier of wagon bridge. The top of brick foundation of pier on west bank is 48.5 feet above gage datum. The drainage area above this point is reported to be 6,900 square miles.

ETOWAH RIVER AT CANTON, GEORGIA.

The headwaters of this stream adjoin those of Chattahoochee River on the east, and the headwater tributaries of Coosawattee River on the west. Its drainage area is on the southern slope of the Blue Ridge Mountains, and it flows westerly into the Gulf drainage. A number of fine water powers occur throughout its length, the one at Cartersville, where it crosses the western fall line, being especially noted. This river joins the Oostanaula at Rome, Georgia, to form Coosa River. Its drainage basin is mapped on the following atlas sheets: Ellijay, Cartersville, and Suwanee. The gaging station was established by the United States Weather Bureau March 12, 1892. It is located at the iron highway bridge over the Etowah River, about 1,000 feet north of and upstream from the Atlanta, Knoxville and Northern Railway station, Canton, Georgia, and about one-half a mile above the mouth of Canton Creek. The bench mark is the top of one of the four pieces of track iron which forms a cap on the left pier, upstream side, and on which the bridge rests, and is at an elevation of 23.30 feet above datum. Up to about 14 feet the river is con-

fined between its banks, but above this stage the river begins to overflow the bottom lands. The reports of discharge measurements are found as follows: 1896, Eighteenth Annual Report, Part IV, page 95; 1897, Nineteenth Annual Report, Part IV, page 242; 1898, Twentieth Annual Report, Part IV, page 189. The following measurements were made by B. M. Hall and his assistants in 1899:

April 27, gage height, 1.92 feet; discharge, 2,087 second-feet.
June 23, gage height, 0.25 foot; discharge, 770 second-feet.
September 27, gage height, —0.19 foot; discharge, 406 second-feet.
November 10, gage height, —0.10 foot; discharge, 420 second-feet.

Long Swamp Creek enters Etowah River 13 miles above Canton, Georgia. On April 21 it was measured at Revis Bridge, near Ballground, Georgia, and showed a discharge of 188 second-feet. Fourmile Creek, a tributary of Long Swamp Creek, was measured April 21 near Ballground, Georgia, and showed a discharge of 20 second-feet. Sharp Mountain Creek enters the Etowah 8½ miles above Canton. On November 10 a measurement of this stream, made by B. M. Hall near Ballground, Georgia, showed a discharge of 34 second-feet.

Daily gage height, in feet, of Etowah River at Canton, Georgia, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.80	1.60	3.00	2.40	1.60	1.00	1.40	1.40	0.80	—0.40	—0.10	0.10
2	1.80	1.60	2.80	2.20	1.50	1.40	1.40	1.40	.60	— .40	— .10	.40
3	1.80	1.80	2.80	2.00	1.40	1.40	1.40	1.80	.60	— .50	— .10	.40
4	1.80	2.80	2.60	3.80	1.40	4.40	1.20	1.60	.60	— .50	— .10	.40
5	1.80	3.00	2.40	3.00	1.40	3.00	1.20	1.60	.60	— .50	— .10	.20
6	1.80	6.20	2.00	2.80	1.40	1.00	1.00	1.40	.60	.00	— .10	.20
7	1.60	8.00	1.80	2.80	1.40	1.00	1.40	1.20	.50	.20	— .10	.20
8	1.40	4.00	1.80	4.00	1.40	1.00	1.60	1.60	.50	.20	— .10	.20
9	1.40	3.20	1.60	3.00	1.60	1.00	4.00	1.80	.40	.20	— .10	.20
10	1.40	3.00	1.50	2.80	1.60	1.00	2.00	1.60	.40	.10	— .10	.20
11	1.40	2.00	1.50	2.00	1.40	1.40	1.80	1.60	.40	.10	— .10	.30
12	1.80	(a)	1.40	1.80	1.40	1.60	1.60	1.60	.40	.10	— .10	2.80
13	1.80	(a)	1.40	1.80	1.40	1.60	1.40	1.40	.40	.00	— .10	.80
14	2.80	(a)	3.60	1.80	1.80	1.40	1.40	1.20	.40	.00	— .10	.30
15	2.60	3.00	7.00	1.80	1.80	1.40	1.80	1.20	.40	.00	.00	.20
16	2.40	2.00	18.20	1.60	1.80	1.40	1.90	1.00	.40	.00	.00	.20
17	2.30	2.00	18.00	1.60	1.60	1.40	1.80	1.00	.30	.00	.10	.20
18	2.30	2.00	4.00	1.60	1.60	1.40	1.80	.80	.80	.00	.00	.10
19	2.20	2.00	4.00	1.40	1.60	1.40	1.80	.80	.30	.00	.00	.10
20	2.20	1.80	3.00	1.40	1.40	1.30	1.60	1.40	.20	— .10	.00	.10
21	2.00	1.80	2.00	1.40	1.40	1.30	1.60	1.40	.10	— .10	.00	.10
22	1.80	1.80	2.00	1.40	1.40	1.30	1.60	1.20	.00	— .10	.00	.10
23	1.80	1.80	2.00	1.40	1.40	1.20	1.60	1.00	.00	— .10	.90	.80
24	2.00	1.60	1.80	1.80	1.40	1.20	1.40	1.00	.00	— .10	.70	3.00
25	2.80	1.40	1.80	4.80	1.40	1.20	1.20	.80	— .10	— .10	.70	3.00
26	2.00	1.80	2.80	3.00	1.20	1.00	1.20	.80	— .10	— .10	1.10	2.00
27	1.80	10.00	2.00	2.80	1.20	1.00	1.20	1.40	— .10	.00	.70	2.30
28	1.80	5.00	1.80	2.00	1.20	1.00	1.20	1.20	— .20	.00	.50	1.80
29	1.80	.....	2.80	1.80	1.20	1.00	1.20	1.00	— .30	— .10	.10	.60
30	10.00	.....	2.00	1.70	1.20	1.00	1.10	1.00	— .30	— .10	.10	.60
31	5.00	.....	2.60	.....	1.00	.....	1.00	.80	.....	— .10	.....	.60

a Gage covered with ice.

COOSAWATTEE RIVER AT CARTERS, GEORGIA.

This river is formed by the junction of Ellijay and Cartecay rivers at Ellijay, Georgia, and flows in a southwesterly direction, joining the Conasauga to form the Oostanaula. Its drainage area is for the

most part mountainous and covered with forest growth. The station was established August 15, 1896, at the iron highway bridge at Carters, Murray County, Georgia, about 20 miles northeast of Calhoun, the most convenient railroad station. It is described in the Eighteenth Annual Report, Part IV, page 96. Carters is the head of navigation, small boats running to Rome, Georgia, and the Coosa River below. It is at the foot of the great shoals made by this stream in cutting through the Cohutta Mountains, the last of which is Carters Shoals, a short distance above the bridge, with a fall of 50 feet. The drainage area above this point is 532 square miles, of which 150 square miles is on the Talking Rock Creek, which enters the river one-half mile above. The basin is mapped on Dalton, Ellijay, Cartersville, and Suwanee atlas sheets. The length of the wire gage is 37.24 feet. The top of the cylindrical iron pier at the right-bank downstream corner of bridge is 30.35 feet above gage datum. The gage was last verified in August, 1898. The current is swift, but is broken by a gravel bar above the section. The bed is gravelly and not apt to change. The banks are high, but occasionally overflow in high water. The observer, H. S. Weems, merchant at Carters, Georgia, gives his services to the Survey without compensation. Records of measurement may be found as follows: 1896 and 1897, Nineteenth Annual Report, Part IV, page 244; 1898, Twentieth Annual Report, Part IV, page 191. The following measurements were made by O. P. Hall and Max Hall in 1899:

January 28, gage height, 2.14 feet; discharge, 868 second-feet.
March 14, gage height, 8.95 feet; discharge, 5,240 second-feet.
March 14, gage height, 7.70 feet; discharge, 4,682 second-feet.
May 26, gage height, 2.35 feet; discharge, 906 second-feet.
June 22, gage height, 1.75 feet; discharge, 653 second-feet.
October 19, gage height, 1.10 feet; discharge, 377 second-feet.

A number of measurements of the tributaries of Coosawattee River have been made during the past season. Ellijay River, at the wagon bridge near Ellijay, Georgia, was measured on October 13, and showed a discharge of 80 second-feet. Talking Rock Creek, which enters Coosawattee River just above Carters Station, was measured twice during the year, the first time on May 26, when the discharge was 144 second-feet, and the second time on June 22, when the discharge was 114 second-feet. April 22 Scared Corn Creek, a tributary of Talking Rock Creek, was discharging 32 second-feet. Sallacoa Creek, which enters Coosawattee River from the south 1 mile above Fields Mill Ferry, was measured on May 20, when the discharge was found to be 103 second-feet. Coosawattee River itself at Fields Mill Ferry, 5½ miles above its junction with the Conasauga, was measured October 14, showing a discharge of 388 second-feet.

Daily gage height, in feet, of Coosawattee River at Carters, Georgia, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.80	2.50	5.00	5.10	3.40	2.00	1.40	1.90	1.00	0.75	0.95	0.95
2	1.90	3.00	4.50	5.00	3.30	1.95	1.50	1.80	1.05	.75	.90	1.30
3	1.90	3.50	3.50	5.20	3.20	1.95	1.40	1.80	1.00	.70	.90	1.20
4	2.00	15.80	3.50	6.00	3.00	1.90	1.40	1.70	1.00	.65	.90	1.20
5	2.05	14.00	6.10	5.80	2.90	2.00	1.45	1.60	.95	.65	.85	1.10
6	2.10	13.20	4.80	5.50	2.90	2.00	1.40	1.50	1.00	.70	.85	1.00
7	2.00	12.50	4.50	5.50	2.80	1.90	1.30	1.45	.95	.70	.80	1.10
8	3.00	8.00	4.00	4.80	2.70	1.90	1.30	1.50	.90	1.50	.80	1.00
9	2.00	6.00	3.20	4.00	2.65	1.85	1.60	1.50	.90	1.20	.90	.90
10	2.00	6.00	3.00	3.70	2.60	1.85	1.50	1.40	.90	1.00	.80	.90
11	2.10	5.00	3.50	3.60	2.50	1.90	1.50	1.40	.95	.90	.80	1.10
12	2.00	4.00	3.50	3.50	2.50	3.20	1.40	1.30	.90	.90	.90	7.40
13	1.90	4.00	4.00	3.40	2.60	3.00	1.40	1.30	.90	.95	.90	5.00
14	1.90	4.50	4.50	3.00	2.60	2.50	1.40	1.60	.90	.90	1.00	3.00
15	2.00	4.50	19.00	3.00	2.50	2.30	1.35	1.50	.85	.90	.90	2.00
16	2.20	4.00	12.00	3.10	2.50	2.20	1.30	1.40	.85	.90	.90	1.50
17	2.80	5.00	10.00	4.00	2.40	2.10	1.70	1.30	.85	.90	1.00	1.30
18	2.60	4.70	9.00	4.00	2.30	2.00	1.50	1.20	.80	.85	1.05	1.10
19	2.40	3.60	7.50	3.75	2.30	1.90	1.60	1.15	.85	.85	1.00	1.10
20	2.30	3.50	6.00	3.50	2.20	1.90	1.80	1.15	.85	.90	1.10	1.20
21	2.10	4.00	5.00	3.40	2.20	1.80	2.20	1.10	.80	.90	1.10	1.20
22	2.10	3.50	8.00	3.50	2.30	1.70	3.00	1.10	.80	.90	1.00	1.40
23	2.00	3.40	7.00	3.50	2.20	1.70	2.50	1.10	.85	.85	.90	1.50
24	2.00	3.50	6.50	4.00	2.15	1.70	2.00	1.05	.85	.85	1.00	3.00
25	2.50	4.00	5.00	6.00	2.15	1.60	2.00	1.05	.80	.80	1.00	2.00
26	2.30	5.00	5.00	5.00	2.10	1.60	3.20	1.10	80	.80	1.20	1.50
27	2.10	15.00	5.20	4.00	2.10	1.50	3.00	1.10	.80	.75	1.10	1.30
28	2.10	7.00	4.80	4.00	2.05	1.50	3.00	1.05	.80	.80	1.05	1.20
29	2.10	.....	4.50	3.70	2.05	1.40	2.20	1.15	.75	1.00	1.00	1.20
30	2.20	.....	4.60	3.60	2.00	1.45	1.90	1.20	.80	1.00	1.00	1.10
31	2.40	.....	4.40	.....	2.00	.....	2.00	1.10	.....	.90	.....	1.10

OOSTANAULA RIVER AT RESACA, GEORGIA.

This river is formed about 3 miles above Resaca by the junction of Coosawattee and Conasauga rivers, the former having a drainage area of 875 and the latter 648 square miles, while there are 4 square miles between the junction and Resaca. This gives a total drainage area of 1,527 square miles, mapped on atlas sheets Cleveland, Ellijay, Dalton, Cartersville, and Suwanee. The station is at the iron railroad bridge of the Western and Atlantic Railroad, in the town of Resaca, Georgia, 1,000 feet from the depot. On July 27, 1896, a discharge measurement was made by Max Hall, and a station established using the Weather Bureau gage. On August 19 a wire gage was established and referred to the same datum. The initial point is the right bank end iron of bridge, downstream side. The length of the wire gage is 43.40 feet. The first bench mark is on the top of capstone of center pier, at an elevation of 36.12 feet; the second is the top of crosstie near center, at an elevation of 40.12 feet. The channel is straight and the current fairly swift. The bed is soft and liable to change; the banks somewhat subject to overflow. The observer is S. M. Barnett, railroad agent at station, who is also the observer for the Weather Bureau. Records of measurement may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 98; 1897, Nineteenth Annual Report, Part IV, page 245; 1898, Twen-

tieth Annual Report, Part IV, page 190. The following measurements were made by Olin P. Hall and Max Hall during 1899:

April 26, gage height, 8.05 feet; discharge, 5,146 second-feet.
May 20, gage height, 4.15 feet; discharge, 1,671 second-feet.
June 9, gage height, 3.10 feet; discharge, 1,171 second-feet.
June 21, gage height, 3.05 feet; discharge, 1,087 second-feet.
October 14, gage height, 1.75 feet; discharge, 644 second-feet.

Three measurements of the discharge of Conasauga River at Fites Ferry, 3½ miles above its mouth, were made during the season. The first, on June 9, gave a discharge of 224 second-feet; second, on June 21, gave a discharge of 258 second-feet, and the third, on October 14, gave a discharge of 122 second-feet.

Daily gage height, in feet, of Oostanaula River at Resaca, Georgia, for 1899 (a).

Day.	Jan.	Feb.	Mar.	Apr.	Nov.	Dec.	Day.	Jan.	Feb.	Mar.	Apr.	Nov.	Dec.
1..	5.10	11.00	16.20	13.40	1.80	2.30	17...	6.10	12.10	28.60	6.20	2.00	3.30
2..	5.00	8.80	9.60	10.30	1.70	2.50	18...	6.25	11.40	27.30	6.00	1.80	2.80
3..	4.50	7.95	8.00	8.40	1.70	2.60	19...	5.65	10.20	26.60	6.10	1.80	2.70
4..	4.20	16.00	7.40	8.10	1.70	2.30	20...	5.10	9.55	26.20	6.00	1.80	3.50
5..	4.10	19.90	9.30	10.20	1.70	2.20	21...	4.85	8.10	27.30	5.80	1.70	4.40
6..	4.50	21.90	10.40	9.00	1.70	2.10	22...	4.70	8.20	25.20	5.60	1.70	3.60
7..	7.50	25.50	9.40	8.90	1.60	2.00	23...	4.50	8.65	21.10	5.40	2.30	3.30
8..	9.35	26.50	7.50	14.30	1.60	2.00	24...	4.55	7.70	17.00	6.40	2.80	8.10
9..	8.80	25.50	6.80	13.90	1.60	1.90	25...	5.50	6.90	11.00	8.60	2.30	8.10
10..	6.20	22.20	6.60	12.70	1.60	2.00	26...	5.30	6.40	9.00	8.70	2.70	6.00
11..	5.85	15.80	6.40	8.90	1.60	2.10	27...	4.80	17.50	8.60	7.00	3.80	4.30
12..	6.00	8.20	6.10	7.80	1.70	5.10	28...	4.55	20.20	7.90	6.30	3.40	3.80
13..	5.80	7.00	6.00	7.40	1.70	8.00	29..	4.40	.....	11.65	5.80	2.80	3.70
14..	5.30	6.35	8.00	7.00	1.70	6.40	30...	4.20	.....	11.40	5.50	2.50	3.50
15..	5.50	6.70	16.00	6.80	1.60	4.00	31...	6.10	.....	11.40	.....	.....	3.00
16..	5.15	6.70	22.00	6.50	1.90	3.60							

a No records from May 1 to October 31.

MEASUREMENTS OF LARGE SPRINGS IN NORTHWEST GEORGIA.

In the basin of Sallacoa Creek, a tributary of Coosawattee River, and in the adjoining basin of Oothkalooga Creek, are a number of large springs which were measured by Olin P. Hall in 1899. On May 30 Dooley Spring, 3 miles south of Fairmount, Georgia, gave a discharge of 0.92 second-foot; Doves Mill Spring, near Cash, Georgia, 16.2 second-feet; Bakers Mill Spring, 5 miles south of Fairmount, Georgia, 3.9 second-feet. June 24 a number of springs in the basin of Sallacoa Creek showed discharges as follows: Colima Spring, near Colima, Georgia, 0.28 second-foot; Arnold Spring, 1 mile south of Colima, 0.38 second-foot; J. R. Byrd's spring, 2½ miles northwest of Fairmount, Georgia, 0.47 second-foot; R. W. Lander's spring, 3 miles east of Pinelog, Georgia, 4.27 second-feet; J. A. Johnson's spring, 2½ miles east of Pinelog, Georgia, 0.48 second-foot; Oakhill Church Spring, 2½ miles east of Pinelog, Georgia, 1.85 second-feet.

The five following springs occur in the basin of Oothkalooga Creek, which enters Oostanaula River 1 mile below Calhoun. On June 26 their discharge was measured and found to be as follows: Hayse

Spring, at Folsom, Georgia, 0.35 second-foot; Cedar Spring, at Mostetters Mill, 1¼ miles west of Folsom, 4.45 second-feet; Trimble Spring, 2 miles north of Adairsville, Georgia, 2.35 second-feet; Gardners Spring, 5 miles north of Adairsville, 0.41 second-foot; Blackwood Spring, 5 miles southeast of Calhoun, Georgia, 1.00 second-foot.

COOSA RIVER AT ROME, GEORGIA.

Coosa River is formed by the junction of Etowah and Oostanaula rivers at Rome, Georgia. The drainage area is 3,720 square miles. Both of the tributary rivers rise in the northern part of Georgia and flow for the most part through a hilly, broken country, well wooded, about one-fourth of the land being under cultivation. The Coosa River flows in a southwesterly direction into Alabama and joins the Tallapoosa 6 miles above Montgomery, Alabama, to form Alabama River. Measurements of flow are made at Rome and at Riverside, 120 miles farther downstream, and will be made in 1900 at Montgomery and Selma. The measurements at Rome are made on the Oostanaula and Etowah just above their junction. Etowah River is measured at Second avenue bridge and the Oostanaula at Fifth avenue bridge in Rome, and the results added to give the flow of Coosa River. The gage height is taken from the United States Weather Bureau gage at Fifth avenue bridge, on the Oostanaula. There is practically no fall on Oostanaula River from Fifth avenue bridge to the junction, hence the gage is used as Coosa River gage and gives the fluctuations of Coosa River. This gage is a 4 by 6 inch timber, graduated to feet and tenths and fastened to the downstream left-hand corner of the first pier from the left bank. The zero of gage is 575.79 feet above sea level. The United States Weather Bureau has maintained the station here for many years. It is now maintained only as a half-year station, from November 1 to April 30, inclusive, but W. M. Towers, the river observer, kindly reads the gage and furnishes the Survey with monthly reports of the daily gage heights for the entire year without charge. Mr. Towers has kept the records for many years and has predicted floods with great precision. The channel of the Etowah is straight, current swift and unobstructed, but the Oostanaula is rather sluggish and somewhat obstructed by piers. The banks are high, but liable to overflow in times of high water. Records of measurements may be found as follows: 1897, Nineteenth Annual Report, Part IV, page 198; 1898, Twentieth Annual Report, Part IV, page 184. The following measurements have been made by Max Hall and others during 1899:

January 25, gage height, 3.80 feet; discharge, 6,540 second-feet.
January 25, gage height, 3.60 feet; discharge, 5,932 second-feet.
May 19, gage height, 2.75 feet; discharge, 4,894 second-feet.
June 16, gage height, 2.40 feet; discharge, 3,352 second-feet.
August 4, gage height, 1.45 feet; discharge, 2,835 second-feet.
October 13, gage height, 0.60 foot; discharge, 1,769 second-feet.

Daily gage height, in feet, of Coosa River at Rome, Georgia, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.00	6.90	19.70	13.20	4.00	3.00	1.70	2.20	3.40	0.40	0.7	1.1
2	3.40	7.80	15.00	10.60	3.70	2.60	1.50	1.90	2.00	.30	.6	1.1
3	3.00	6.00	8.60	7.90	3.70	2.60	1.00	1.70	1.60	.30	.5	1.5
4	2.70	9.20	6.60	7.20	3.50	2.00	.90	1.50	1.40	.30	.5	1.3
5	2.60	15.30	7.80	9.50	3.50	2.00	2.00	1.40	1.30	.30	.4	1.1
6	2.60	18.20	9.00	8.20	3.50	2.00	1.90	1.50	1.30	.50	.4	1.0
7	3.60	27.80	8.00	8.20	3.70	2.00	1.90	1.60	1.20	.70	.3	.9
8	5.90	24.00	6.80	15.00	3.70	1.90	3.00	1.50	1.00	.70	.3	.8
9	5.90	22.40	5.70	13.40	3.60	1.80	2.10	1.80	1.00	.80	.3	.8
10	4.90	21.00	5.40	11.20	3.50	1.80	1.90	1.60	1.00	.60	.3	.8
11	4.00	19.00	5.20	9.50	3.30	1.80	2.50	1.40	2.90	1.00	.3	.8
12	4.50	16.50	4.90	7.00	3.10	2.20	2.80	1.40	2.30	.90	.3	2.8
13	4.00	7.00	4.50	6.40	3.10	3.80	2.00	1.20	1.50	.70	.3	6.1
14	3.80	5.00	6.00	5.90	3.00	4.00	1.60	1.10	1.00	.70	.4	5.0
15	3.60	5.00	16.60	5.60	3.00	3.50	1.30	1.30	.90	.60	.4	3.2
16	3.60	5.50	27.70	5.40	2.90	2.50	1.80	1.90	.80	.60	.5	2.0
17	4.00	8.90	29.20	5.20	2.80	2.10	5.20	1.60	.60	.60	.9	1.8
18	4.20	9.50	25.80	4.80	2.80	2.00	4.20	1.40	.60	.60	.7	1.7
19	4.00	8.50	24.90	4.70	2.80	2.00	4.80	1.10	.60	.60	.5	1.3
20	3.70	7.70	26.20	4.60	2.80	2.00	8.80	.90	.70	.60	.5	1.6
21	3.30	6.80	24.60	4.30	2.60	1.80	12.80	.90	.70	.70	.5	2.0
22	3.20	6.90	23.00	4.10	2.60	2.20	7.90	.80	.60	.70	.4	2.0
23	3.10	7.30	22.60	4.00	2.40	1.70	4.80	.80	.60	.60	1.0	1.8
24	3.50	6.60	21.90	5.40	2.60	1.70	3.90	.70	.50	.50	2.1	7.2
25	3.80	5.80	18.00	7.40	2.50	1.70	2.60	.70	.50	.40	1.5	7.5
26	3.80	5.50	10.50	9.10	2.40	1.70	2.60	.70	.50	.40	2.5	5.0
27	3.30	19.10	7.70	6.70	2.20	2.10	3.80	2.50	.50	.40	3.0	3.5
28	3.00	23.40	6.80	5.50	2.20	1.90	3.00	2.50	.60	.40	2.2	3.0
29	3.00	.....	8.80	4.80	2.00	1.90	2.40	2.50	.50	.40	1.9	3.0
30	2.90	.....	9.30	4.20	2.00	1.80	1.40	2.00	.40	.50	1.4	3.4
31	4.40	.....	10.20	.....	3.30	.....	1.20	2.50	.....	.80	.....	2.0

COOSA RIVER AT RIVERSIDE, ALABAMA.

This station, described in the Eighteenth Annual Report, Part IV, page 99, was established September 25, 1896, at the bridge of the Southern Railway across Coosa River near Riverside, Alabama. The drainage area is 6,850 square miles. It is mapped on the Springville, Anniston, Gadsden, Fort Payne, Rome, Tallapoosa, Marietta, Cartersville, Suwanee, Ellijay, Dalton, Cleveland, Ringgold, and Stevenson atlas sheets. The town of Riverside is on the west bank of the river, and the railroad station is 1,000 feet west of the bridge at which the measurements are made. The length of the gage wire is 38.35 feet. The first bench mark is the top capstone on the large circular center pier of turn-span, the elevation of which is 26.80 feet above gage datum; second bench mark is base of rail near same pier, and is 32.80 feet above gage datum. The channel is straight, current swift, but somewhat obstructed by a ledge of rock under water about 300 feet above the station. The observer is J. W. Foster, Riverside, Alabama. The records of measurement may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 101; 1897, Nineteenth Annual Report, Part IV, page 248; 1898, Twentieth Annual Report, Part IV, page 187. The following measurements were made by Max Hall and others during 1899:

April 26, gage height, 9.00 feet; discharge, 29,069 second-feet.
May 3, gage height, 4.05 feet; discharge, 10,592 second-feet.
May 20, gage height, 2.70 feet: discharge, 6,276 second-feet.
June 14, gage height, 2.20 feet: discharge, 5,010 second-feet.

August 26, gage height, 1.42 feet; discharge, 3,791 second-feet.
September 23, gage height, 1.00 foot; discharge, 2,457 second-feet.
November 7, gage height, 0.85 foot; discharge, 2,271 second-feet.
December 9, gage height, 1.20 feet; discharge, 2,727 second-feet.

Daily gage height, in feet, of Coosa River at Riverside, Alabama, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.80	5.90	12.10	10.30	5.00	2.70	1.70	3.95	2.30	0.90	0.95	2.60
2	2.75	6.30	12.20	10.20	4.50	2.80	1.70	3.00	2.40	.90	.95	2.00
3	2.75	7.50	12.30	10.00	4.20	2.80	1.65	2.30	2.80	.90	.95	1.60
4	2.80	7.40	12.10	9.80	3.95	2.60	1.60	2.00	2.40	.90	.95	1.50
5	2.80	9.10	10.10	8.90	3.80	2.30	1.50	1.90	2.10	.90	.95	1.45
6	3.00	12.10	9.00	8.75	3.75	2.10	1.50	1.75	2.00	.90	.95	1.40
7	3.50	14.10	8.00	9.00	3.60	2.00	1.45	1.65	1.85	.90	.95	1.35
8	4.30	14.30	7.50	10.00	4.00	2.00	1.40	1.50	1.40	.90	.95	1.30
9	4.20	14.30	7.25	12.30	3.85	1.95	1.70	1.50	1.30	.95	.95	1.30
10	4.40	14.10	7.00	12.00	3.60	1.95	1.60	1.55	1.25	1.20	.95	1.35
11	5.20	13.80	6.15	11.70	3.45	1.95	1.50	1.55	1.25	1.30	.95	1.40
12	5.90	13.00	5.20	10.00	3.30	1.95	1.50	1.60	2.20	1.40	.95	5.80
13	5.60	12.00	5.50	8.90	3.20	2.00	1.40	1.50	2.50	1.30	.95	8.25
14	5.00	10.90	7.50	7.90	3.00	2.15	1.40	1.45	2.65	1.20	1.00	8.00
15	4.70	8.70	8.30	6.30	3.00	2.80	1.30	1.50	2.00	1.20	1.00	6.00
16	4.90	7.90	16.00	5.55	2.95	3.20	1.30	1.50	1.40	1.20	1.00	4.50
17	5.00	7.60	17.40	5.25	2.95	2.95	1.30	1.50	1.25	1.10	1.00	3.75
18	4.90	7.80	17.00	5.10	2.80	2.50	1.20	1.55	1.20	1.00	1.00	3.60
19	4.70	8.10	16.50	5.00	2.80	2.25	1.30	1.50	1.20	.95	1.00	3.40
20	4.60	8.20	16.30	4.80	2.75	2.00	1.50	1.45	1.10	.95	1.00	3.00
21	4.20	8.00	16.35	4.60	2.75	1.80	1.50	1.45	1.00	.90	.95	2.85
22	4.00	7.65	16.20	4.30	2.70	1.70	1.90	1.35	.95	.90	.95	2.75
23	3.90	8.00	15.90	4.75	2.70	1.70	3.20	1.30	1.00	.95	.95	3.00
24	3.90	8.10	15.70	5.65	2.65	1.60	4.70	1.30	1.00	1.20	.95	5.40
25	4.00	7.30	15.50	8.90	2.60	1.75	3.60	1.30	1.00	1.15	1.00	6.40
26	4.25	7.00	14.90	9.00	2.50	1.60	3.20	1.60	1.00	1.00	2.15	7.10
27	4.15	8.30	13.25	8.90	2.45	1.60	3.00	1.20	.95	1.00	2.90	7.00
28	4.00	11.00	11.00	8.30	2.35	1.65	3.60	1.10	.95	.95	3.00	6.60
29	3.90	.....	8.00	6.90	2.30	1.70	4.20	1.50	.90	.95	3.00	6.00
30	3.75	.....	7.90	5.45	2.20	1.65	5.20	2.10	.90	.90	2.75	4.85
31	3.70	.....	8.50	.....	2.70	.....	4.75	2.10	.....	.95	.....	4.00

COOSA RIVER AT LOCKS NOS. 4 AND 5, ALABAMA.

The station at Lock No. 4 is located 3 miles above Riverside, Alabama. Measurements here give the discharge past Riverside except the small quantity, about 1 cubic foot per second, flowing into the Coosa from Blue Spring Branch. The measurements are made from the bridge of the Southern Railway at Riverside. A record has been kept at Lock No. 4 by the United States Engineer Corps. The first section of the vertical gage rod is fastened to the lower end of the cofferdam, 500 feet below the dam on the river. The second section is fastened to a sycamore tree, 150 feet below rod. The zero of rod is 477.30 feet above the Mobile datum. The bench mark is a brass point in a stone post 1,000 feet up the river from lower gage, and is 510.55 feet above Mobile datum.

The station at Lock No. 5 is described in the Eighteenth Annual Report, Part IV, page 101, and is located one-half mile above the Birmingham and Atlantic Railroad crossing and about 20 miles below gaging station at Riverside, Alabama. The gage is vertical in two sections, fastened to the trees immediately above the landing of Collins Ferry. The zero of the gage is 460.37 feet above Mobile datum. Bench mark No. 1, which is on the tree to which one section of the rod is fastened, is 471.80 feet above Mobile datum. Bench mark No. 2 is

center of iron plate at top of cylindrical pier, at right bank upstream side of the railroad bridge, and is at an elevation of 493.91 feet Mobile datum. Records of river height are kept by the United States Engineer Corps, and are kindly furnished to the Survey. Measurements of discharge are not made at either of these stations.

Daily gage height, in feet, of Coosa River, at Lock No. 4, Alabama, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.0	7.6	14.0	11.6	5.5	2.8	1.9	4.5	2.2	0.4	0.5	2.2
2	3.0	7.7	14.2	11.7	5.2	2.9	1.8	3.3	2.3	.4	.5	1.9
3	3.3	8.8	14.2	11.1	4.8	2.9	1.6	2.5	3.2	.5	.6	1.4
4	3.5	8.6	13.5	10.6	4.6	2.6	1.5	2.0	2.5	.5	.6	1.4
5	3.3	10.7	11.4	9.8	4.3	2.2	1.4	1.8	1.8	.5	.6	1.4
6	3.3	14.2	9.5	8.6	4.2	2.2	1.3	1.7	1.4	.5	.6	1.4
7	3.9	15.9	9.2	9.8	4.1	2.7	1.3	1.7	1.3	.5	.6	1.3
8	5.0	16.4	8.9	12.8	4.6	2.7	1.3	1.5	1.3	.5	.5	1.1
9	5.4	16.4	8.3	14.0	4.4	2.0	1.6	1.4	1.2	.8	.5	1.0
10	6 0	16.1	7.3	13.9	4.3	1.9	1.8	1.5	1.0	1.1	.5	1.0
11	6.4	15.8	6.5	13.2	4.0	1.9	1.7	1.5	.9	1.0	.5	1.0
12	6.6	15.5	6.1	11.6	4.0	1.9	1.5	1.6	1.0	1.0	.5	6.7
13	6.0	14.9	5.8	10.0	3.8	2.0	1.5	1.5	2.5	1.3	.5	9.4
14	5.8	13.9	8.5	8.1	3.8	2.0	1.4	1.4	2.8	.8	.5	9.8
15	5.5	10.6	9.4	7.1	3.3	2.7	1.3	1.3	1.8	.9	.5	7.4
16	5.1	7.5	19.7	6.6	3.3	3.7	1.3	1.4	1.3	.2	.6	5.8
17	5.4	7.8	20.2	6.2	3.3	2.7	1.1	1.2	1.0	.3	.6	4.3
18	5.8	8.6	19.1	5.9	3.0	2.2	1.1	1.5	.9	.3	.5	3.4
19	5.7	9.6	18.5	5.7	3.0	1.9	1.1	1.9	.8	.4	.4	2.8
20	5.4	9.6	18.8	5.4	3.0	2.0	1.1	1.7	.7	.4	.4	2.4
21	5.0	9.1	18.8	5.2	3.0	2.0	1.5	1.4	.7	.4	.8	2.6
22	4.6	8.8	18.7	5.1	2.8	1.8	1.6	1.2	.6	.4	.6	3.0
23	4.3	9.7	18.4	5.5	2.8	1.7	2.2	1.0	.4	.4	.7	3.0
24	4.3	9.3	18.0	6.8	2.7	1.7	5.6	.9	.3	.4	.8	5.9
25	4.8	8.6	17.5	10.6	2.9	1.7	5.5	1.0	.3	.2	.8	7.6
26	4.9	7.7	17.0	10.5	3.0	1.6	3.8	1.4	.4	.6	2.2	8.3
27	4.9	11.2	16.7	10.5	2.7	1.6	3.4	1.0	.4	.6	3.1	7.8
28	4.6	12.9	15.2	9.8	2.7	1.5	3.4	1.0	.4	.5	3.4	6.3
29	4.3	.....	12.7	8.0	2.7	1.8	4.1	1.5	.5	.6	3.1	5.4
30	4.0	.....	9.5	6.0	2.4	1.8	6.3	2.1	.4	.5	2.8	4.4
31	.....	.....	9.5	.....	3.0	.....	5.3	2.3	.....	.5	.....	3.8

Daily gage height, in feet, of Coosa River at Lock No. 5, Alabama, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.7	3.9	10.5	8.6	3.3	1.3	0.8	2.5	1.0	0.1	0.1	1.0
2	1.7	4.7	10.4	8.8	2.9	1.4	.7	1.7	1.1	.1	.1	.8
3	1.7	5.7	10.4	8.1	2.7	1.5	.6	1.2	1.1	.1	.1	.6
4	1.7	5.6	10.0	7.6	2.5	1.4	.6	.9	1.0	.1	.1	.5
5	1.7	7.1	8.9	7.4	2.3	1.2	.6	.7	.8	.1	.1	.5
6	1.6	10.1	6.7	6.7	2.2	1.0	.5	.7	.6	.1	.1	.5
7	1.9	12.1	6.4	7.6	2.1	.9	.4	.7	.5	.1	.1	.4
8	2.8	12.5	6.0	10.0	2.0	.9	.5	.6	.5	.1	.1	.4
9	3.0	12.4	5.4	11.0	2.3	.9	.5	.6	.4	.1	.1	.4
10	3.3	12.0	4.7	10.5	2.2	.8	.7	.6	.4	.2	.1	.4
11	4.1	11.6	4.0	9.7	2.0	.8	.7	.5	.3	.3	.1	.4
12	4.1	11.4	3.7	8.5	2.0	.9	.6	.5	.3	.3	.1	4.0
13	3.7	10.9	4.3	7.0	1.8	.9	.6	.5	.3	.4	.1	5.6
14	3.4	10.0	6.0	5.4	1.8	1.0	.5	.5	1.3	.4	.1	6.2
15	3.2	7.8	6.7	4.6	1.7	1.3	.5	.5	.8	.3	.1	5.4
16	3.0	4.8	14.8	4.0	1.7	1.8	.4	.8	.5	.2	.1	4.6
17	3.0	5.0	15.4	3.9	1.6	1.6	.4	.5	.3	.2	.1	2.4
18	3.3	5.6	14.5	3.6	1.5	1.3	.4	.5	.3	.1	.1	1.6
19	3.2	6.2	14.0	3.4	1.5	1.0	.4	.8	.2	.1	.1	1.3
20	3.0	6.4	14.1	3.2	1.5	.9	.3	.6	.2	.1	.1	1.2
21	2.8	6.0	14.0	3.1	1.5	.8	.5	.6	.1	.1	.1	1.2
22	2.5	5.8	14.0	3.0	1.4	.8	.8	.4	.1	.1	.1	1.3
23	2.3	6.4	14.0	3.0	1.3	.7	1.4	.4	.1	.1	.1	1.4
24	2.3	6.1	13.5	4.0	1.3	.7	2.9	.4	.1	.1	.1	2.4
25	2.6	5.6	13.0	7.1	1.3	.7	3.0	.4	.1	.1	.1	4.6
26	2.7	5.0	12.7	7.2	1.3	.6	2.1	.4	.1	.1	.8	5.3
27	2.7	9.5	12.4	7.2	1.3	.6	1.7	.4	.1	.1	1.5	4.9
28	2.5	9.6	11.0	6.6	1.1	.6	1.9	.3	.1	.1	1.7	3.8
29	2.3	.....	9.5	5.3	1.1	.7	2.6	.5	.1	.1	1.4	2.8
30	2.1	.....	7.1	4.0	1.0	.9	3.8	1.0	.1	.1	1.3	2.3
31	2.2	.....	6.9	.....	1.3	.....	3.1	1.0	.....	.1	.....	1.9

COOSA RIVER AT WETUMPKA, ALABAMA.

This station is located at gage No. 1, 3 miles above Wetumpka, Alabama, and was established November 5, 1889, by the United States Engineer Corps, who have maintained daily gage readings since that date until December 31, 1898, when the station was abandoned. The gage heights here are affected by backwater from Tallapoosa River at high stages of the latter stream, so that the record does not show the true flow of Coosa River. Discharge measurements can not be made at the Wetumpka bridge, as it is located directly over a shoal. Discharge measurements will be made next year at Montgomery, 10 miles below Wetumpka, but below the mouth of Tallapoosa River, and at Selma, 45 miles below Montgomery, at both of which points Weather Bureau stations are maintained.

TALLAPOOSA RIVER AT MILSTEAD, ALABAMA.

Tallapoosa River rises in the west-central part of Georgia and flows in a southwesterly direction into Alabama, where it joins the Coosa, to form Alabama River, 6 miles above Montgomery, Alabama. Its upper tributaries drain an area between the Chattahoochee and Coosa basins. At Tallassee, Alabama, it crosses the southern fall line. The shoals at this place have a fall of 60 feet, forming an obstruction to navigation. The drainage area is largely wooded, with cultivated fields at short intervals. A gaging station was established at Milstead on August 7, 1897, at the bridge of the Tallassee and Montgomery Railway, about one-fourth of a mile from Milstead, Alabama. The bridge is of iron, two spans of about 155 feet each, with short wooden trestles at each end. The initial point of measurement is the end of iron bridge, left bank, downstream side. The rod of wire gage is fastened to outside of guard rail on downstream side of bridge. The gage was last verified April 18, 1899. The bench mark is top of second cross beam from left-bank pier, downstream end, and is 60.00 feet above datum. The channel is straight at the bridge, and bends above and below. The current is sluggish at low water and obstructed by center pier of bridge. The banks are high, but overflow at extreme high water for several hundred feet on each side. The bed is fairly constant, and all water is confined to the main channel by railroad embankments. The observer is Seth Johnson, a farmer and fruit grower, Milstead, Alabama. Records of discharge measurements may be found as follows: 1897, Nineteenth Annual Report, Part IV, page 250; 1898, Twentieth Annual Report, Part IV, page 193.

The following measurements were made by Max Hall during 1899:

April 17, gage height, 6.34 feet; discharge, 7,444 second-feet.
April 18, gage height, 5.63 feet; discharge, 6,853 second-feet.
May 17, gage height, 2.80 feet; discharge, 3,000 second-feet.
June 26, gage height, 2.05 feet; discharge, 1,847 second-feet.
September 9, gage height, 1.36 feet; discharge, 1,016 second-feet.
November 8, gage height, 1.25 feet; discharge, 972 second-feet.
December 18, gage height, 2.66 feet; discharge, 2,844 second-feet.

Two measurements of Big Sandy Creek, a tributary of Tallapoosa River, were made September 11. The first, near the bridge 4 miles from Dadeville, Alabama, showed a discharge of 79 second-feet and the second, at a point a short distance above the bridge, showed a discharge of 74 second-feet.

Daily gage height, in feet, of Tallapoosa River at Milstead, Alabama, for 1899.

Day.	Jan.	Feb	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	5.00	17.00	27.00	18.00	4.30	2.40	2.80	3.00	2.40	0.70	1.50	2.40
2	4.60	11.60	19.00	12.20	4.00	2.90	2.30	2.70	2.30	.70	1.40	2.50
3	3.90	24.50	13.50	6.50	3.90	2.40	1.90	3.10	2.10	.80	1.40	2.60
4	3.90	20.00	9.60	6.40	3.80	2.40	1.80	3.10	2.00	.90	1.30	2.60
5	3.90	12.90	14.20	8.50	3.70	2.30	1.60	2.50	1.80	1.00	1.30	2.90
6	3.80	11.90	13.20	9.70	3.60	2.20	1.50	2.30	1.60	1.40	1.20	2.20
7	7.40	17.50	10.10	10.30	3.50	2.10	1.50	2.20	1.60	1.40	1.20	2.00
8	8.00	27.00	8.60	13.00	3.60	2.00	2.00	2.00	1.40	1.30	1.20	1.90
9	7.10	19.00	7.70	13.00	3.50	1.90	2.20	1.80	1.40	1.30	1.20	1.80
10	6.40	13.80	7.20	11.20	3.40	1.70	2.00	1.60	1.30	1.30	1.20	1.90
11	18.50	10.00	6.80	8.40	3.30	1.90	1.80	1.50	1.20	1.40	1.30	2.00
12	16.80	8.30	6.60	7.00	3.20	2.00	1.70	1.70	1.20	1.40	1.30	15.20
13	13.00	7.40	6.50	6.50	3.10	2.00	1.50	1.60	1.20	1.30	1.30	13.20
14	11.60	7.00	6.40	6.20	3.10	2.70	1.40	1.60	1.10	1.30	1.30	8.20
15	9.40	6.10	7.20	6.00	3.00	2.70	1.30	1.50	1.00	1.20	1.30	5.00
16	7.80	10.40	12.20	7.10	2.90	2.60	1.30	4.00	1.00	1.10	1.30	3.70
17	12.70	11.50	11.00	6.60	2.80	2.10	1.20	3.90	1.00	1.20	1.60	3.00
18	10.00	10.60	10.20	5.60	2.70	1.90	1.10	2.20	1.00	1.10	1.50	2.60
19	8.00	9.30	14.80	5.50	2.60	1.80	1.60	1.90	1.10	1.20	1.50	2.50
20	6.50	8.30	13.90	5.40	2.50	1.80	1.40	1.70	1.00	1.30	1.50	2.70
21	5.70	8.30	10.40	5.20	2.60	1.70	8.40	1.50	.90	1.40	1.40	2.70
22	5.30	8.40	8.30	5.00	2.70	1.50	16.75	1.60	1.00	1.50	1.40	2.70
23	5.10	7.60	8.10	4.90	2.60	1.50	14.00	2.00	1.00	1.60	1.60	2.60
24	5.20	6.90	12.70	6.00	3.30	1.50	16.95	2.60	.90	1.80	1.80	9.30
25	5.20	6.40	8.70	10.00	4.60	1.50	7.90	1.90	.90	1.50	2.20	9.40
26	5.10	6.30	7.30	7.50	3.30	2.00	6.70	1.80	.90	1.40	4.60	7.20
27	4.80	25.00	6.90	6.60	2.80	2.50	6.80	3.70	.90	1.30	6.20	5.00
28	4.70	37.00	6.80	5.80	2.60	2.50	8.40	2.80	.80	1.20	4.80	4.00
29	5.10	.....	9.00	4.90	2.50	2.20	10.10	2.10	.80	1.50	3.60	3.50
30	5.20	.....	8.90	4.60	2.60	2.70	5.40	1.90	.80	1.50	2.80	3.10
31	6.50	.....	13.85	.....	2.50	.....	4.40	2.30	.....	1.60	.....	2.90

ALABAMA RIVER AT MONTGOMERY, ALABAMA.

This river is formed by the junction of Coosa and Tallapoosa rivers 6 miles above Montgomery. The basin is described at length under the descriptions of its two tributaries. A gage rod was established by the United States Engineer Corps a number of years ago at the Montgomery wharf, near the Union Passenger Station, at foot of Commerce street. The readings are now taken by the Weather Bureau and are furnished to our Survey. The gage rod is in six sections, as follows: Section 1, from 2 to 10 feet on fender pile at face of

wharf, 108 feet from lower end; section 2, from 10 to 15 feet at upper end of pile protection to Louisville and Nashville Railroad bank in corner pile, and the 15-foot mark is 1.1 feet above the top of pile; section 3, 15 to 27 feet on bent in center of drain, on the lower side of Commerce-street sewer; section 4, 27 to 36 feet, on upper side of sewer, third bent; section 5, 36 to 46 feet, same side of sewer, sixth bent; section 6, 46 to 50 feet, same side of sewer, seventh bent. The rods are of pine timber, painted and graduated to feet and tenths. There are also two new sections, 15 to 25 feet and 25 to 37 feet, on trees about 50 yards south of the old gage. The bench mark is northeast corner of stone doorsill, north door of Windsor Hotel, on Commerce street, and is 57.68 feet above zero of gage. This latter datum is 103.7 feet above sea level. The high-water mark for Montgomery is 59.7 feet, and was reached in April, 1886. The danger line is placed at 35 feet. The width of the river at low water is 690 feet. No discharge measurements at this station were made during 1899, but will probably be made in the coming year, and in that case the measurements will be made at the iron bridge of the Louisville and Nashville Railroad, about 3 miles above Montgomery. This bridge is 60.6 feet above low water, with three spans over the river, the center one being a draw or turn span.

Daily gage height, in feet, of Alabama River at Montgomery, Alabama, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	5.0	13.0	35.1	20.3	9.8	3.2	2.3	9.4	3.1	—0.3	0.4	3.3
2	5.2	14.9	35.2	21.5	8.4	3.5	2.5	7.2	2.6	— .4	.2	2.8
3	5.1	19.0	33.5	21.4	7.3	3.7	2.3	6.8	2.2	— .4	.1	2.5
4	5.0	23.0	30.3	19.0	6.7	3.8	2.0	5.6	2.1	— .3	.0	2.3
5	4.8	23.5	27.0	17.2	6.3	3.6	1.7	4.8	2.5	.2	.0	2.0
6	4.8	22.1	25.6	16.8	6.0	3.2	1.5	3.8	1.9	.1	.0	1.7
7	5.3	24.8	18.7	16.4	5.8	3.0	1.2	3.4	1.7	.2	— .1	1.5
8	7.4	28.9	16.1	20.3	5.6	2.8	1.2	3.2	1.3	.3	— .1	1.4
9	8.5	31.6	14.3	22.3	5.8	2.6	1.3	2.9	.5	.3	— .1	1.3
10	8.9	32.0	13.2	24.2	6.3	2.5	1.5	2.5	.9	.2	— .1	1.0
11	11.0	31.6	12.1	24.0	6.3	2.4	1.7	2.2	.9	.2	— .1	7.5
12	17.5	29.7	10.9	22.1	5.7	2.3	1.7	2.0	.8	.4	— .1	14.6
13	18.0	26.8	9.8	19.4	5.1	2.4	1.5	1.7	.6	.6	— .1	15.6
14	16.3	24.7	13.2	17.1	5.1	2.6	1.3	1.5	.5	.4	— .1	15.5
15	13.9	20.6	16.0	14.1	5.0	2.8	1.1	1.4	1.3	.5	— .1	14.6
16	12.7	19.2	18.3	12.0	4.8	3.3	1.0	1.3	1.8	.4	— .1	11.4
17	12.4	17.6	24.9	10.4	4.4	3.4	.9	2.3	1.0	.2	.0	7.5
18	13.0	16.5	29.0	9.8	4.3	3.5	.9	3.5	.8	.1	.1	5.9
19	13.1	15.9	30.8	9.3	4.0	3.1	.9	2.8	.5	.1	.1	4.6
20	10.0	15.9	31.7	9.0	3.9	2.2	1.4	1.8	.4	.2	.1	4.0
21	8.4	16.0	32.0	8.5	3.8	1.7	1.8	1.8	.0	.4	.1	3.7
22	7.8	15.4	32.0	8.1	3.8	1.5	4.8	1.5	.0	.5	.0	3.6
23	7.8	14.7	31.4	8.2	3.8	1.2	9.0	1.5	— .1	.8	.4	3.5
24	8.9	13.5	30.0	9.4	4.9	1.2	13.7	1.8	— .1	.4	.5	9.6
25	8.9	13.5	30.0	11.0	5.2	1.2	16.0	2.0	— .1	.4	.6	10.5
26	9.0	13.5	28.3	14.8	5.2	1.6	11.7	1.5	— .1	.3	1.0	11.2
27	9.1	24.0	27.4	16.7	4.3	1.8	8.3	1.7	— .2	.2	3.0	12.0
28	9.0	33.0	26.1	16.7	3.8	2.1	9.5	2.7	— .2	.1	4.0	10.6
29	8.7	.....	24.9	15.8	3.5	2.3	10.4	2.8	— .3	.1	3.8	8.6
30	8.7	.....	23.9	12.2	3.1	2.1	10.4	1.9	— .3	.4	3.3	6.9
31	9.0	.....	19.3	.....	3.0	.....	9.2	1.9	.....	.4	.....	5.5
Mean.	9.5	21.2	24.2	15.6	5.2	2.5	4.3	2.9	0.9	0.2	0.6	6.7

ALABAMA RIVER AT SELMA, ALABAMA.

This station is located 45 miles by railroad below Montgomery, and was originally established by the United States Engineer Corps. Readings are now taken by the Weather Bureau. The gage rod is a pine plank painted white with black marks, and is in two sections. Section 1, 3 feet to 23 feet, is fastened to the pile on the lower side of the cofferdam on the draw pier. Section 2, 23 feet to 48 feet, is spiked to the bridge. The bench mark is an iron bolt driven in the face of a rock bluff, 182.3 feet from center of north face of pier and above the bridge, and is 26.05 feet above zero of the gage. The high-water mark is 57 feet, and was reached April 8, 1886. The danger line is placed at 35 feet. The rod is attached to the iron highway bridge, the floor of which is about 60 feet above low water. There is a turn-span at one end. The section is good for measurements, with a width of about 300 feet at low water. No measurements of discharge were made here during 1899.

Daily gage height, in feet, of Alabama River at Selma, Alabama, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	6.2	10.8	35.8	23.8	13.9	4.5	2.5	11.1	3.7	—1.2	—0.2	4.8
2	6.2	17.0	36.8	24.3	11.5	4.0	2.5	9.9	4.3	—1.3	— .3	3.7
3	6.5	20.2	38.8	24.9	9.9	4.0	2.6	9.0	4.6	—1.3	— .5	3.0
4	6.2	24.0	37.7	24.1	9.8	4.0	2.6	6.7	4.8	—1.3	— .6	3.0
5	6.2	26.8	35.3	22.3	8.5	3.8	2.1	6.5	4.4	—1.1	— .7	2.8
6	5.8	27.2	32.6	20.9	8.1	3.9	1.6	5.8	4.4	—1.0	— .7	2.8
7	6.6	27.2	30.5	20.0	7.5	3.8	1.6	5.3	4.1	—1.6	— .8	1.7
8	8.3	29.8	27.5	19.8	7.4	3.7	1.5	4.7	3.9	— .5	— .8	1.7
9	9.7	32.2	23.4	23.3	7.3	3.3	1.4	4.5	3.6	— .4	— .8	1.3
10	11.6	33.9	19.7	25.6	7.3	3.1	1.3	3.7	.6	— .4	— .9	1.3
11	13.9	34.4	16.9	26.9	7.5	2.8	1.3	3.5	.4	— .5	— .9	1.4
12	14.8	33.9	15.0	26.6	7.2	2.3	1.2	3.0	.3	— .6	— 1.0	4.0
13	21.2	32.0	13.9	25.1	6.8	2.6	1.5	2.9	.3	— .6	—1.1	10.4
14	21.9	30.0	16.2	22.6	6.5	2.4	1.2	2.7	.2	— .2	— 1.2	16.6
15	19.8	28.0	16.8	19.5	6.3	2.4	1.1	2.6	.2	— .2	— 1.2	17.8
16	18.0	26.5	19.4	16.3	6.2	2.3	1.0	2.6	.1	— .2	— 1.3	16.3
17	17.5	26.8	21.4	14.0	6.1	2.8	1.0	2.6	.6	— .3	—1.3	13.4
18	17.2	24.0	27.7	13.0	5.6	3.4	.7	3 6	1.3	— .5	—1.3	9.9
19	17.0	22.3	31.6	12.0	5.4	3.9	.6	4.1	1.0	— .7	—1.2	8.4
20	15.8	19.9	33.5	11.2	5.0	3.9	.6	4.3	.9	— .6	—1.0	3.8
21	14.2	19.9	34.7	10.5	4.8	3.1	1.0	3.6	.6	— .7	—1.0	3.8
22	12.6	19.5	34.8	10.4	4.5	2.8	1.6	3.5	— .6	— .8	— .6	3.4
23	10.2	18.8	34.2	10.2	4.4	1.6	5.5	3.4	— .7	— .2	— 6	3.4
24	10.3	17.8	33.4	10.1	4.8	1.4	10.7	3.1	— .8	.0	— .3	3.8
25	9.4	17.3	31.1	12.4	5.0	1.4	14.8	3.6	—1.0	.0	.1	7.6
26	9.0	16.4	32.6	13.5	6.0	1.6	17.0	4.2	—1.0	— .5	.2	12.2
27	8.9	20.3	31.8	16.3	6.1	1.7	17.0	3.9	—1.0	— .5	.9	13.5
28	8.6	31.2	30.5	17.9	5.2	2.0	14.9	3.6	—1.0	— .6	3.2	13.7
29	8.6	.....	29.3	17.7	4.5	2.2	13.1	4.3	—1.1	— .6	4.6	12.3
30	9.0	.....	27.8	16.1	4.3	2.4	12.8	4.6	—1.1	— .6	4.8	11.4
31	9.6	.....	26.3	.....	4.2	.....	11.9	3.8	.....	— .4	.....	8.3
Mean.	11.6	24.6	28.3	18.4	6.7	2.9	4.8	4.5	1.2	— .6	— .2	7.1

CATAWBA RIVER NEAR BIRMINGHAM, ALABAMA.

A measurement of this river, a tributary of Alabama River, was made by Mr. S. Hill Lea, civil engineer, in June, 1897, at a point 7 miles northeast of Birmingham, Alabama. The stage of the river was considered to be that of average low water. The mean velocity of the current was found to be 2.56 feet per second, and the discharge 817 second-feet.

BLACK WARRIOR RIVER AT TUSCALOOSA, ALABAMA.

The Black Warrior River rises in the south-central part of Alabama and flows in a southwesterly direction into the Tombigbee, on the southern boundary of Greene County. Tombigbee River flows southward from the junction until it reaches Alabama River, with which it unites to form Mobile River. The drainage area is for the most part flat, open country, much of it being under cultivation. Above Tuscaloosa it is largely in a Carboniferous formation, containing pervious strata, porous shales, and limestone caves, through which considerable water is probably lost. A continuous record of gage height at Tuscaloosa since 1889 has been kept by the United States Engineer Corps. During 1895 and 1896 a number of discharge measurements were also made, from which a rating table was obtained, and since that time measurements of flow have been made regularly by the United State Geological Survey, and computations made of the discharge. This station is described in the Eighteenth Annual Report, Part IV, page 103, and is located about three-fourths of a mile from the business center of Tuscaloosa, Alabama. It is reached by passing down Bridge street to the river, thence down the east bank 1,800 feet to the gage, which consists of an inclined timber 2 by 6 inches, supported on posts and graduated by means of notches placed 1 foot apart vertically. There are two bench marks, one on a willow tree, 10 feet west of gage, and 97.84 feet above Mobile datum: the other on a small hackberry, 30 feet south of the upper end of the gage, and 139.36 feet above Mobile datum. The zero of gage is 87.30 feet above same datum. The discharge measurements are made from the highway bridge above the gage. The channel is straight and unobstructed. The current is sluggish at time of low water; the banks high and rocky and not subject to overflow. The observer is R. C. McCalla, jr., United States assistant engineer. Records of measurement may be found as follows: From 1889 to 1896, Eighteenth Annual Report, Part IV, page 108; 1897, Nineteenth Annual Report, Part IV, page 251; 1898, Twentieth Annual Report, Part IV, page 194. The following measurements were made by B. M. Hall and Prof. George S. Wilkins, of the University of Alabama, in 1899:

Measurements of Black Warrior River at Tuscaloosa, Alabama.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Sec. feet.*	1899.	*Feet.*	*Sec. feet.*
February 21	19.36	12,855	March 4	23.70	12,609
February 21	19.25	12,640	March 14	31.18	36,653
February 24	22.85	16,216	March 14	34.37	40,331
February 28	39.47	48,010	March 17	59.50	119,533
March 1	35.50	24,988	March 18	56.40	86,410
March 2	30.35	18,052	March 23	40.30	23,911

Daily gage height, in feet, of Black Warrior River at Tuscaloosa, Alabama, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.40	26.10	37.70	30.30	7.90	2.00	0.10	6.50	1.20	−1.50	−1.08	4.83
2	4.50	29.50	32.00	29.20	7.00	1.50	.80	4.90	.70	−1.61	−1.02	3.50
3	4.60	27.00	27.70	24.80	6.30	1.20	.30	3.40	.62	−1.80	−1.03	2.77
4	4.70	29.00	24.10	22.00	5.80	1.00	−.70	2.70	.23	−1.79	− .99	2.03
5	4.70	45.50	21.00	23.20	5.30	1.00	−.10	2.00	− .02	−1.51	−1.00	1.50
6	11.20	50.60	20.80	22.60	4.80	.90	−.30	1.90	− .17	−1.48	−1.02	1.22
7	42.50	51.40	19.50	23.30	4.40	1.00	−.20	1.80	− .38	−1.46	−1.03	.98
8	49.30	51.70	16.90	33.90	4.40	.80	−.30	1.30	− .40	−1.34	−1.03	.88
9	46.60	48.60	14.40	34.00	7.60	.40	−.40	1.20	− .46	−1.30	−1.03	.58
10	40.40	43.10	12.90	30.80	6.50	.40	−.40	1.10	− .68	− .96	−1.01	.60
11	35.70	37.80	11.90	27.00	5.10	.50	−.40	2.00	− .73	− .78	−1.01	2.20
12	31.90	32.80	11.30	23.60	4.30	.50	−.50	1.70	− .79	− .72	− .98	23.50
13	28.00	28.80	10.00	20.10	4.20	.50	−.60	1.30	− .71	− .70	− .96	39.53
14	25.00	25.70	28.80	17.20	4.30	.50	−.60	.90	− .73	− .88	− .98	35.71
15	22.20	22.90	44.50	14.90	4.70	.50	−.70	.60	− .78	− .94	− .99	26.50
16	20.00	21.60	59.30	13.00	4.30	.70	−.70	.40	− .83	−1.06	−1.00	20.63
17	19.60	19.90	60.30	11.60	3.70	.60	−.70	.30	− .86	−1.07	− .97	15.21
18	20.10	20.10	57.70	10.50	3.30	.40	−.70	.30	− .88	−1.12	− .97	10.83
19	18.60	20.80	52.40	9.80	2.80	.30	−.70	.60	− .90	−1.16	− .95	8.02
20	16.10	20.60	49.38	9.60	2.70	.20	−.70	.60	− .92	−1.12	− .95	8.09
21	14.00	19.60	46.80	9.50	3.70	.10	−.60	.70	− .94	−1.10	− .92	9.63
22	12.20	18.50	41.60	8.70	3.80	.40	−.50	1.50	− .99	− .84	− .89	10.80
23	11.00	22.70	36.80	8.60	3.30	−.10	−.20	2.60	−1.03	− .73	− .33	10.63
24	11.00	23.10	33.00	11.30	3.10	−.10	+.60	2.50	−1.05	− .71	+ .17	22.01
25	20.30	20.90	29.50	13.60	2.70	−.60	4.90	2.60	−1.04	− .88	.88	29.04
26	29.30	18.50	26.50	13.20	2.30	+.20	7.60	2.30	−1.05	− .94	2.60	25.91
27	26.20	23.50	24.20	12.60	2.00	.20	7.40	2.10	−1.04	−1.02	4.50	20.98
28	22.50	39.00	22.30	11.40	1.75	.20	7.90	1.90	−1.18	− .60	10.48	17.09
29	18.60	.....	21.10	10.00	1.50	.20	9.50	1.60	−1.28	− .73	9.49	15.80
30	15.70	.....	19.30	8.90	1.60	.10	9.30	1.50	−1.38	− .96	6.67	14.62
31	14.80	.....	18.10	.....	2.50	.....	8.50	1.10	.....	−1.03	.....	12.51

The United States Weather Bureau has maintained gage readings at Demopolis, Alabama, on Tombigbee River, at the mouth of the Black Warrior River. The distance to Mobile is 185 miles. The gage rod is on the steamboat landing, and is 225 feet in length. From the bottom of the rod to the top of the bluff the gage is constructed of 2 by 12 inch pine boards set edgewise in a trench cut in the bank and securely fastened, the upper edge faced with three-eighths by 2 inch iron graduated to feet and tenths. At the top of the bluff to a point 5 feet above highest water the gage is marked by rows of copper tacks on a 6 by 8 inch post set firmly in the ground. The bench mark is the top of water table on the north side of the city jail at the western end, and is 68.40 feet above zero of gage and 13.71 feet below top of track of Southern Railway at the freight depot. The highest water was 66 feet, on April 18, 1874; the lowest, 3.9 feet, on October 26 to 30, 1875. The danger line is at 35 feet.

ALLEGHENY RIVER.

Allegheny River, which with the Monongahela forms the Ohio at Pittsburg, rises in northern Pennsylvania, flows northerly into the State of New York, then again turning southerly flows through western Pennsylvania. The headwaters have an elevation of about 2,250 feet and adjoin those of Genesee River on the north and of the Susquehanna on the east. The total length from the source to the mouth at Pittsburg is about 300 miles, 47 miles of which are in New York State. The catchment basin on the upper waters attains the

height of from 2,600 to 2,800 feet above sea level. The principal facts concerning this river have been given in a report by Mr. George M. Lehman, assistant engineer, contained in House Document No. 72, Fifty-fifth Congress, third session. The total area of the watershed as measured from the map of the Pennsylvania geological survey, is 11,400 square miles. The principal tributaries making up this total with their area in square miles are as follows: Conewago Creek, including Chautauqua Lake watershed, 935; Tionesta Creek, 458; French Creek, 1,180; Clarion River, 1,175; Redbank Creek, 526; Mahoning Creek, 397; Kiskiminitas River, 1,846, and Allegheny River above mouth of French Creek, about 5,950. The average fall of the river below Oil City is 2.2 feet per mile, but there are several stretches where for several miles the fall reaches nearly 5 feet per mile. Between Oil City and Tarentum, a distance of 112.6 miles, there are 81 ripples, some of them at very low water having only 0.5 foot depth of water; the depths in quiet water are in many places from 10 to 20 feet. The distance between Oil City and Tarentum, the part of the river surveyed and reported upon in 1897 by the United States Engineer Corps, and where the river is quite winding, is 112.6 miles by river channel and 57 miles by air line. The distance by river channel from Pittsburg to Franklin is 126.4 miles and the railroad distance 124 miles. The following table, furnished by Mr. George M. Lehman, was made in connection with the survey of the river by the United States Engineer Corps in 1897. It shows the heights above low water of 1865 and 1898:

Height of Allegheny River above low water in 1865 and 1898.

Distance from Pittsburg.	Place.	Width between banks.	Flood—	
			1865.	1898.
Miles.		*Feet.*	*Feet.*	*Feet.*
134.0	Oil City	800	22.5	12.5
126.4	Franklin (French Creek)	1,050	23.2	12.0
110.0	Kennerdell	900	26.5	13.5
91.6	Emlenton	500	31.3	19.0
85.0	Parker (Clarion River)	1,000	26.0	16.2
80.5	Monterey	700	32.0	20.5
70.7	East Brady	700	33.0	23.5
65.0	Redbank Junction (Redbank Creek)	950	24.5	18.0
56.2	Mahoning (Mahoning Creek)	1,000	28.3	23.5
45.6	Kittanning	1,000	30.3	25.0
38.2	Logansport	750	28.0	28.0
28.7	Freeport (Kiskiminitas River)	850	32.0	28.5
21.6	Tarentum	1,500	28.5	24 0
0	Pittsburg	1,000	31.4	29.0

It is said that the highest flood occurred in 1832, when the water rose to a height of 36 feet at Pittsburg. The flood of 1865 is the highest known, at least for any great extent of river and for which it was possible to get fairly reliable information. The depths show that the rainfall was quite general over the watershed, particularly

above Oil City. There is a very gradual and slight increase toward Pittsburg. The flood of 1898 was high on the lower Allegheny; the records show heavy rainfall over the watersheds of tributaries south of Clarion River, and the depths indicate this. The width of river has strong influence in depths, as shown in list.

Other high floods than those mentioned above have occurred at Pittsburg, but they have not all come from Allegheny River. The flood of 1884 backed water for several miles up from the mouth of the Monongahela, the depth recorded being 34.5 feet above low water. The flood of 1889 rose to 31.3 feet, but at points above the vicinity of Pittsburg the heights ranged about halfway between those of the 1865 and 1898 floods. The high water of 1865 is locally known as the "oil flood," because of the fact that many hundred barrels of oil awaiting shipment by steamboat from the Oil City district were carried downstream.

Observations of the discharge of the Allegheny at Pittsburg at the time of the 1898 flood were made by Mr. George M. Lehman on the velocity of drift passing between the bridges. The current averaged 7.7 miles per hour, and the estimated discharge was 290,000 second-feet.

YOUGHIOGHENY RIVER AT FRIENDSVILLE, MARYLAND.

This river rises in Garrett County, Maryland, and flows in a northwesterly direction into Pennsylvania, where it empties into Monongahela River 15 miles above Pittsburg. Its source is on the western slope of the Allegheny Mountains, at an elevation of about 2,900 feet. The average fall of the stream for 19 miles above its mouth is about 2 feet per mile, but above this point it soon increases to an average fall of nearly 5 feet per mile. The bank height above low water ranges between 15 and 28 feet, and the average width between banks from the mouth to West Newton, Pennsylvania, is 546 feet. The following heights at various points in Pennsylvania of the high water of February, 1897, above low-water stage, was furnished by Mr. George M. Lehman: Whikett, 13 feet; Jacobs Creek, 10 feet; Smithton, 14 feet; Port Royal, 17 feet; Snyder, 16 feet; West Newton, 20 feet; Suterville, 22 feet; Buena Vista, 26.5 feet; Coulterville, 28.5 feet; Boston, 29 feet; McKeesport, 28.5 feet.

A measurement of Youghiogheny River was made October 13, 1892, with surface floats, at Ohio Pyle, Pennsylvania, by Mr. Kenneth Allen, in connection with an investigation of a water supply for the works of the H. C. Frick Coke Company. It was during a period of extreme drought, and the discharge was found to be 106 second-feet. The area of its watershed was approximately obtained from maps of uncertain accuracy, but was called 1,775 square miles.

The station at Friendsville, Maryland, was established by E. G. Paul August 17, 1898. Measurements are made from the iron high-

way bridge connecting the east and west portions of the village. The wire gage is 20 feet from zero to the end of the weight, and referred to a scale board 14 feet long, graduated to feet and tenths. The channel is straight for several hundred feet above and below the bridge. The bed is rocky and the banks high and not subject to overflow. The observer is J. H. Cuppet, a merchant residing within a short distance of the gage. The results of measurements for 1898 may be found in the Twentieth Annual Report, Part IV, page 199. The following measurements were made by E. G. Paul during 1899:

January 24, gage height, 5.40 feet; discharge, 959 second-feet.
January 25, gage height, 6.35 feet; discharge, 2,050 second-feet.
May 17, gage height, 5.97 feet; discharge, 1,697 second-feet.
June 30, gage height, 5.40 feet; discharge, 944 second-feet.

Daily gage height, in feet, of Youghiogheny River at Friendsville, Maryland, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	5.20	5.00	6.50	6.50	4.60	4.90	5.20	4.50	4.00	4.10	4.10	4.30
2	5.20	4.90	6.40	6.30	5.00	4.90	4.80	4.30	4.10	4.10	4.60	4.30
3	5.20	5.00	6.30	6.00	5.20	4.80	4.60	4.20	4.00	4.10	5.00	4.30
4	5.40	7.40	6.30	5.80	5.30	4.80	4.40	4.20	4.00	4.10	4.80	4.30
5	6.50	7.00	7.70	5.30	5.30	4.80	4.60	4.60	3.90	4.00	4.50	4.30
6	6.30	6.20	8.20	5.20	5.20	4.60	4.50	4.80	3.90	4.00	4.50	4.50
7	6.10	5.90	6.60	5.10	5.20	4.50	4.50	4.50	3.90	4.00	4.40	4.60
8	6.00	5.60	6.20	6.90	5.10	4.50	4.50	4.30	4.10	4.00	4.30	4.60
9	5.80	5.40	5.90	6.50	6.90	4.40	4.40	4.20	4.00	4.00	4.30	4.80
10	5.60	5.30	6.30	5.90	6.50	5.20	4.40	4.20	4.40	4.00	4.40	4.90
11	5.30	5.20	6.10	5.70	6.30	5.90	4.30	4.30	4.40	3.90	4.30	4.90
12	5.20	5.10	6.00	5.50	5.90	5.80	4.20	4.20	4.30	3.90	4.20	5.40
13	5.10	5.10	5.90	5.30	5.60	5.60	4.20	4.20	4.30	3.90	4.20	5.80
14	6.10	Frozen	5.70	5.20	5.60	5.60	4.30	4.20	4.20	3.90	4.20	5.50
15	8.00	...do..	5.60	5.10	5.50	5.70	4.40	4.10	4.10	3.90	4.20	5.30
16	7.10	...do..	5.60	5.10	5.60	6.50	4.60	4.10	4.10	3.90	4.10	5.10
17	6.80	...do..	5.70	5.00	5.70	6.20	4.60	4.10	4.00	3.90	4.10	5.10
18	6.50	..do..	5.70	5.00	8.00	5.40	4.90	4.00	4.00	3.90	4.10	5.20
19	6.20	5.10	5.70	5.00	9.50	5.00	4.70	4.00	4.10	3.90	4.30	5.40
20	5.80	5.20	5.70	4.90	7.20	4.80	4.50	4.00	4.10	3.90	4.40	5.40
21	5.50	5.40	6.00	4.90	6.90	4.80	4.40	4.00	4.30	3.90	4.60	5.30
22	5.40	6.80	6.00	4.80	6.50	4.70	4.30	4.00	4.20	3.90	4.70	5.30
23	5.30	7.20	6.30	4.70	6.10	4.60	4.20	4.00	4.20	3.90	4.60	5.30
24	5.30	6.40	6.30	4.70	5.60	4.50	4.20	4.00	4.10	3.90	4.60	5.20
25	6.40	6.90	6.00	4.70	5.30	5.30	4.40	4.00	4.00	3.90	4.60	5.20
26	6.00	6.20	5.80	4.60	5.10	5.10	4.20	4.00	4.00	3.90	4.40	5.20
27	5.70	7.90	5.60	4.60	4.90	5.20	4.20	4.00	4.10	3.90	4.40	5.10
28	5.50	7.20	6.60	4.70	4.90	5.20	4.20	4.00	4.10	4.00	4.40	5.10
29	5.30	.....	8.00	4.70	4.80	5.40	4.40	4.10	4.10	4.00	4.40	5.10
30	5.10	.....	7.30	4.60	4.90	5.60	4.30	4.10	4.10	4.00	4.30	5.10
31	5.10	.....	6.90	.....	4.90	.....	4.30	4.00	.....	.....	.....	5.10

CHEAT RIVER AT UNEVA, WEST VIRGINIA.

This river rises in the eastern part of West Virginia, and flows almost due north across the Pennsylvania boundary, entering Monongahela River 3 miles north of the State line. The drainage area is partly mapped on the St. George, Piedmont, Franklin, Beverly, Monterey, and Huntersville atlas sheets. As there is no bridge at a place convenient for making measurements, a cable of 600 feet span was stretched across the stream 6 miles northeast of Morgantown, at Uneva, West Virginia, and observations of heights begun on July 8,

1899. The gage is a post bolted to a rock and graduated to feet and tenths. The initial point of soundings is on the right bank. The channel above and below the station is straight. The current is sluggish. The right bank is low and subject to overflow, but the left bank is high and rocky. The bed of the stream is rocky and constant. The observer is A. F. Blosser, a blacksmith at Uneva, West Virginia. On July 8, 1899, a measurement at this station was made by E. G. Paul, at a gage height of 2.60 feet, and gave a discharge of 1,148 second-feet. A measurement was made of this river during a period of extreme drought at Morris crossroads, Pennsylvania, 1 mile below the West Virginia State line, on October 6, 1892, by Mr. Kenneth Allen, and the discharge found to be 249 second-feet.

Daily gage height, in feet, of Cheat River at Uneva, West Virginia, for 1899.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	3.00	2.20	2.00	3.70	2.90	17	3.50	2.40	2.70	1.80	2.40	3.40
2	.....	2.80	2.00	2.00	4.00	2.80	18	3.40	2.30	2.30	1.80	2.40	3.20
3	.....	2.70	2.30	1.90	3.80	2.70	19	3.00	2.20	2.20	1.70	2.50	3.00
4	.....	2.50	2.20	1.90	3.50	2.70	20	2.80	2.10	2.00	1.70	3.40	4.80
5	.....	3.40	2.20	1.90	3.30	2.60	21	2.40	2.00	1.90	1.60	3.40	4.40
6	.....	3.30	2.20	1.90	3.10	2.60	22	2.40	2.00	1.90	1.60	3.20	4.10
7	.....	3.00	2.10	1.80	2.10	2.50	23	2.40	1.90	2.30	1.60	3.00	3.90
8	2.60	2.80	2.00	1.80	2.10	2.50	24	2.30	1.90	2.20	1.60	3.00	5.20
9	3.00	2.70	2.00	1.80	2.80	2.50	25	2.50	1.80	2.20	1.60	3.90	4.40
10	2.80	2.60	2.20	1.70	2.70	2.50	26	2.70	1.80	2.10	1.70	3.70	3.60
11	2.70	2.50	4.10	1.70	2.60	2.70	27	2.80	1.80	2.30	1.70	3.50	3.20
12	2.50	2.40	3.80	1.70	2.90	5.50	28	2.60	2.50	2.40	1.70	3.30	2.90
13	2.40	2.30	3.50	1.70	2.70	6.40	29	2.50	2.40	2.30	1.70	3.10	2.70
14	2.50	2.20	3.20	1.70	2.60	4.80	30	3.50	2.30	2.20	1.70	3.10	2.60
15	2.80	2.20	3.00	1.70	2.60	4.20	31	3.60	2.30	.....	1.70	.....	.....
16	2.80	2.30	2.80	1.70	2.50	3.80							

The United States Weather Bureau have maintained gage readings on Cheat River at Rowelsburg, West Virginia, 36 miles above its junction with the Monongahela. The river at this point is 270 feet wide. The drainage area above the station is reported to be 890 square miles. The gage rod is on the second pier of the Baltimore and Ohio Railroad bridge. The bench mark of the United States Coast and Geodetic Survey, situated on the center pillar, west end of the bridge, is 26.66 feet above zero of the gage. The highest water was 22 feet, on July 10, 1880; lowest, 0.9 foot, on October 15, 1895. The danger line is at 14 feet.

NEW RIVER AT RADFORD, VIRGINIA.

This river rises in Watauga, Ashe, and Alleghany counties, North Carolina, and flows in a northwesterly direction into West Virginia, where it meets the Gauley, near Kanawha Falls, to form the Great Kanawha. The drainage area is mapped on the Kanawha Falls, Nicholas, Hinton, Beverly, Monterey, Huntersville, Lewisburg, Raleigh, Christiansburg, Dublin, Pocahontas, Abingdon, Wytheville, Hillsville, Yadkinville, Wilkesboro, and Cranberry topographic sheets. The upper tributaries have a general northeasterly and southwesterly direction, draining the narrow valleys of the greater Appalachian

Valley in Virginia. The basin of New River is for the most part mountainous and wooded, forming one of the most beautiful and picturesque sections in the eastern part of the United States. The river itself is rapid and a part of it almost impassable, even for canoes. Systematic measurements of flow of New River are made at Radford, Montgomery County, Virginia, and at Fayette, West Virginia. The station at Radford is located at the highway bridge close to the Norfolk and Western Railway station. It was established by D. C. Humphreys August 1, 1898. The gage used was erected by the United States Weather Bureau. It consists of a vertical board graduated to feet and tenths, and is attached to the iron framework connecting the pair of iron concrete cylinders which form the first pier from the right bank. The bench mark is the bottom of the lowest horizontal brace connecting the two cylinders, the elevation being 3.88 feet above the zero of the gage. The discharge measurements are made from the upstream side of the bridge. The initial point of soundings is on the right bank of the river 40 feet from the first pier. The bottom is of solid rock and gravel and is smooth and regular. On the left bank there is a steep, rocky bluff. The right bank is low and subject to overflow for about 100 yards, but all the water must pass under the bridge, which is about 85 feet above low water. The observer is A. J. Killinger, bridge tender at Radford, Virginia. The following measurements were made by D. C. Humphreys during 1899:

June 29, gage height, 1.12 feet; discharge, 4,980 second-feet.
August 11, gage height, 0.20 foot; discharge, 2,172 second-feet.

Daily gage height, in feet, of New River at Radford, Virginia, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.00	0.70	3.00	2.40	1.40	1.10	0.80	0.00	1.00	0.30	0.40	—0.30
2	1.10	.70	2.60	2.00	1.30	1.00	.40	.00	1.00	.20	1.00	— .30
3	1.00	1.70	2.00	1.90	1.30	.90	.40	.00	1.00	.00	.90	— .20
4	1.20	2.00	6.05	1.60	1.40	.80	.30	.00	1.10	.00	.60	— .30
5	1.50	3.90	10.50	2.00	1.30	.70	.30	.00	1.00	.00	.30	— .10
6	1.80	5.70	7.00	1.90	1.00	.60	.40	.00	.10	.00	.20	— .10
7	4.00	5.00	5.00	1.80	1.10	.40	.50	.00	.00	.00	.00	— .10
8	2.60	4.20	4.00	4.10	1.20	.40	.40	.00	.00	.20	.00	— .10
9	1.80	3.10	2.90	3.80	1.90	.30	.30	.00	.00	.10	.00	— .20
10	1.70	3.00	2.50	2.90	1.80	.30	.20	.00	.00	.00	.00	+ .10
11	1.60	2.40	2.20	2.90	2.00	.40	.30	.00	.00	.00	.00	.20
12	1.20	2.00	2.00	1.90	1.90	1.00	.30	.00	.00	.00	.00	1.75
13	1.50	1.90	1.90	1.80	2.00	3.90	.40	.00	.00	.00	.00	4.20
14	1.40	1.30	1.70	1.70	2.10	2.60	.20	1.00	.00	.00	.00	2.90
15	1.50	.90	3.00	1.80	1.80	2.00	.10	.50	.00	.00	.00	1.00
16	1.60	1.20	6.10	1.60	1.70	1.70	.00	.40	.00	.00	.00	.90
17	1.70	3.50	3.70	1.50	1.30	1.10	.00	.20	.00	.00	.20	.80
18	1.20	3.20	2.90	1.40	1.10	.90	.00	.20	.00	.00	.90	.80
19	1.10	3.60	7.75	1.60	1.00	.80	.00	.10	1.00	.00	.00	.70
20	1.10	2.80	7.90	1.50	1.00	.90	.00	.20	1.60	.00	.00	.90
21	.90	3.00	4.00	1.40	.90	.70	.10	.30	1.00	.00	.00	1.00
22	.80	3.00	3.80	1.30	.80	.60	.10	.30	.90	.00	.00	.90
23	1.00	2.90	3.00	1.30	1.10	.50	.10	.20	.80	.00	.00	.60
24	1.00	2.00	2.80	1.10	1.50	.50	.00	.00	.60	.00	.00	.60
25	.90	1.90	2.60	1.00	1.40	.60	.00	.00	.50	.00	.00	.50
26	1.00	2.00	2.50	2.00	1.10	.90	.00	.00	.50	.00	.00	.40
27	1.00	4.60	2.00	2.50	.80	1.20	1.00	.00	.40	.00	.00	.30
28	.90	4.00	3.10	2.00	.80	1.00	.90	1.00	.30	.00	.00	.30
29	1.00	-------	3.00	1.80	.70	1.00	.80	1.10	.40	.00	—.20	.20
30	.80	-------	3.20	1.60	.80	.90	.50	1.00	.30	.10	—.30	.20
31	.80	-------	2.90	-------	.80	-------	.40	1.00	-------	.00	-------	.20

GREENBRIER RIVER AT ALDERSON, WEST VIRGINIA.

This river rises on the western slope of the Allegheny Mountains, in Pocahontas County, West Virginia, and flows in a southwesterly direction, emptying into New River near Hinton, Summers County, West Virginia. The station was established by C. C. Babb and D. C. Humphreys, at Alderson, West Virginia, 21 miles above Hinton, August 1, 1895. The drainage area at this point is 1,344 square miles, and is mapped on Hinton, Beverly, Monterey, Huntersville, and Lewisburg atlas sheets. Greenbrier River receives many short tributaries from the Allegheny Range, and flows for the most part through a hilly, broken, and mountainous country well covered with forests. The station, described in the Eighteenth Annual Report, Part IV, page 111, is located one-half mile above the mouth of Muddy Creek, on the county bridge at Alderson. The wire gage, length 28.37 feet, is in the third panel of the second span, downstream side, and was last verified on August 12, 1899. This gage is referred to three bench marks: The first, on the upper end of the coping of the first pier from the left bank, 21.75 feet above zero of the gage; the second, on upper end of the bridge seat of the left bank abutment, 21.61 feet above the zero of the gage; the third, on stone foundation of water tank of the Chesapeake and Ohio Railway, 23.48 feet above the zero of the gage. A temporary bench mark has been established on lower end of third floor beam, in second span from left bank. Elevation 22.47 feet above the zero of the gage. The bridge consists of four spans 435 feet long. At ordinary stages the water flows in two channels, there being an island 600 feet long and 75 feet wide between them. The banks are high and not subject to overflow. The bed is of rock and gravel and fairly constant. The observer is W. J. Hancock, clerk in a hardware store, Alderson, West Virginia. Records of measurement can be found as follows: 1895–96, Eigtheenth Annual Report, Part IV, page 113; 1897, Nineteenth Annual Report, Part IV, page 254; 1898, Twentieth Annual Report, Part IV, page 204. The following measurements were made by D. C. Humphreys during 1899:

June 22, gage height, 1.94 feet; discharge, 456 second-feet.
August 12, gage height, 1.36 feet; discharge, 104 second-feet.

Daily gage height, in feet, of Greenbrier River at Alderson, West Virginia, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.80	2.63	5.75	4.13	2.42	2.75	1.78	1.48	1.30	1.48	1.37	1.52
2	2.75	2.90	4.95	3.68	2.40	3.15	1.75	1.43	1.40	1.42	1.48	1.50
3	3.08	2.38	6.10	3.35	2.77	3.20	1.73	1.43	1.38	1.42	1.58	1.45
4	2.75	2.27	12.98	3.13	2.60	2.90	1.72	1.33	1.35	1.42	1.58	1.45
5	3.52	4.58	15.38	2.90	2.55	2.65	1.67	1.48	1.45	1.40	1.60	1.45
6	5.35	6.21	10.95	2.83	2.52	2.47	1.61	1.35	1.42	1.40	1.68	1.45
7	8.60	5.80	6.45	2.75	2.66	2.34	1.58	1.22	1.37	1.40	1.62	1.45
8	6.00	4.50	4.90	3.00	5.38	2.25	1.61	1.35	1.47	1.40	1.58	1.42
9	4.60	3.68	4.15	4.75	7.30	2.47	1.63	1.95	1.55	1.38	1.53	1.40
10	3.90	3.10	3.90	4.10	6.30	2.27	1.62	1.34	1.47	1.38	1.48	1.40
11	3.50	2.70	3.75	3.58	4.60	2.25	1.64	1.34	1.50	1.35	1.48	1.40
12	3.20	2.65	3.75	3.42	4.30	2.68	1.60	1.36	1.50	1.34	1.48	1.48
13	3.03	2.75	3.60	3.23	4.58	3.30	1.58	1.38	1.47	1.34	1.45	2.20
14	2.98	2.75	3.43	3.15	4.80	2.90	1.60	1.32	1.42	1.37	1.43	2.40
15	3.90	2.80	3.60	3.05	4.35	2.83	1.58	2.30	1.38	1.36	1.43	2.45
16	3.28	2.70	4.05	2.95	3.83	2.75	1.56	2.00	1.40	1.35	1.43	2.20
17	3.95	2.60	4.10	2.85	3.45	2.52	1.52	1.72	1.38	1.35	1.40	2.00
18	3.70	2.68	3.75	2.80	3.15	2.37	1.52	1.60	1.32	1.26	1.40	1.75
19	3.48	2.80	5.05	2.75	3.05	2.23	1.55	1.38	1.40	1.26	1.38	1.73
20	3.23	3.10	6.35	2.70	2.92	2.20	1.58	1.40	1.47	1.30	1.38	1.76
21	3.00	4.40	4.95	2.60	2.88	2.15	1.55	1.35	1.48	1.30	1.42	1.85
22	2.92	6.75	4.20	2.50	2.68	2.03	1.63	1.42	1.42	1.27	1.38	1.75
23	2.90	6.60	3.85	2.45	2.58	1.89	1.60	1.36	1.65	1.22	1.38	1.73
24	2.80	5.25	3.70	2.40	2.52	2.10	1.54	1.37	1.70	1.32	1.38	1.78
25	2.85	4.28	3.50	2.37	2.42	1.95	1.55	1.30	1.60	1.28	1.40	1.73
26	3.30	3.80	3.35	2.60	2.38	1.92	1.50	1.30	1.58	1.25	1.40	2.13
27	3.15	8.63	3.22	2.88	2.27	1.87	1.54	1.28	1.55	1.25	1.38	2.02
28	3.05	7.60	3.17	2.72	2.20	1.90	1.50	1.25	1.58	1.25	1.40	1.80
29	2.97	.....	6.38	2.57	2.17	1.92	1.58	1.37	1.50	1.25	1.53	1.80
30	2.70	.....	5.95	2.50	2.15	1.85	1.52	1.32	1.50	1.22	1.56	1.80
31	2.75	.....	4.65	.....	2.30	.....	1.50	1.32	.....	1.32	.....	1.95

The United States Weather Bureau has maintained gage readings on New River at Hinton, West Virginia. The drainage area above the station is reported to be 6,020 square miles. The railroad track at the depot is 33.5 feet above zero of gage. The highest water was on September 13, 1878, when it reached 23 feet; lowest, 0.5 foot, date unknown. The danger line is at 14.5 feet.

NEW RIVER AT FAYETTE, WEST VIRGINIA.

This station, established by C. C. Babb and D. C. Humphreys July 29, 1895, is described in the Eighteenth Annual Report, Part IV, page 113, and is located just below the mouth of Wolf Creek, on the highway bridge of one span at Fayette, West Virginia. The drainage area is mapped on the Kanawha Falls, Nicholas, Hinton, Beverly, Monterey, Huntersville, Lewisburg, Raleigh, Christiansburg, Dublin, Pocahontas, Abingdon, Wytheville, Hillsville, Yadkinville, Wilkesboro, and Cranberry atlas sheets. The wire gage is on the guard rail on the upper side of the bridge, about the middle of the span, the scale being graduated to feet and tenths. The gage is referred to four bench marks: First, the top of the bottom plate of the lower plate girder at the end of the first panel from the left bank, downstream side, 55.13 feet above the zero of the gage; second, top of lower end of coping on the main pier, right bank, downstream side, 52.13 feet above the zero of the gage; third, bridge seat on the right bank, downstream side, 54.58 feet above the zero of the gage; fourth, west

corner of abutment stone by Chesapeake and Ohio Railway station, 58.62 feet above the zero of the gage. The gage was last verified August 14, 1899. The channel is straight above and below the station, the current is swift and without obstructions, except for immense bowlders in the bottom. The banks are high, rocky, and not subject to overflow. The bed is constant in section. The observer is M. W. Brellahan, agent Chesapeake and Ohio Railway, Fayette, West Virginia. Records of measurement may be found as follows: 1895–96, Eighteenth Annual Report, Part IV, page 115; 1897, Nineteenth Annual Report, Part IV, page 156; 1898, Twentieth Annual Report, Part IV, page 203. The following measurements were made by D. C. Humphreys during 1899: June 22, gage height, 3.65 feet; discharge, 5,097 second-feet; August 14, gage height, 1.80 feet; discharge, 2,985 second-feet.

Daily gage height, in feet, of New River at Fayette, West Virginia, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.45	4.45	9.00	8.40	6.80	6.30	3.80	2.40	2.70	0.95	1.80	0.80
2	4.30	5.00	11.51	8.35	6.25	6.35	3.00	2.30	1.55	.80	2.00	.85
3	4.10	6.40	19.35	6.50	6.00	6.00	3.20	2.20	1.50	.80	1.95	.80
4	4.10	7.25	35.08	6.10	5.85	5.50	3.05	2.40	1.90	.70	1.85	.70
5	4.00	14.20	29.78	5.50	5.70	4.95	2.40	2.25	2.20	.60	1.80	.55
6	5.90	20.60	24.43	5.85	5.75	4.60	2.45	2.15	2.10	.65	1.75	.50
7	13.00	22.80	18.78	7.50	5.65	3.15	2.25	2.00	2.00	.50	1.75	.50
8	10.10	17.10	14.00	8.10	7.55	3.25	2.20	1.85	1.40	.50	2.40	.45
9	6.50	14.35	13.30	7.10	12.40	3.20	2.10	1.40	1.30	2.05	1.65	.35
10	5.20	10.05	10.10	7.05	12.10	3.05	2.05	1.45	1.35	2.40	1.40	.80
11	8.10	8.30	9.50	7.15	8.10	3.05	1.95	1.35	1.45	2.35	1.20	1.00
12	7.50	6.50	9.00	9.80	9.95	3.00	1.90	1.30	1.40	2.65	1.20	1.00
13	7.40	6.10	8.20	8.00	8.25	6.85	2.05	1.35	1.30	2.60	1.15	1.70
14	6.45	5.30	8.00	7.55	8.90	11.60	1.85	1.40	1.30	2.60	1.10	9.50
15	6.15	4.50	8.40	7.00	10.70	11.75	1.45	1.50	1.25	2.45	1.10	8.30
16	5.80	4.30	8.25	6.75	9.50	10.30	1.35	2.10	1.20	2.40	1.05	4.60
17	5.50	4.45	10.50	6.65	8.00	7.05	1.30	2.70	1.15	2.30	1.05	3.25
18	5.05	6.50	10.10	6.00	6.60	6.00	1.40	2.15	1.20	2.15	1.00	2.95
19	4.75	6.85	15.00	5.55	5.95	5.30	1.35	1.45	1.20	2.10	1.00	2.80
20	4.35	6.20	20.00	5.55	5.65	5.05	1.40	1.40	1.15	2.10	1.00	2.85
21	4.10	9.40	17.60	5.50	5.20	4.35	1.80	1.30	1.10	2.05	.90	3.05
22	4.20	11.25	11.40	5.40	5.05	4.10	1.90	1.25	1.15	2.05	.90	3.10
23	5.55	10.10	8.30	5.40	5.00	3.50	1.75	1.25	1.10	2.00	.90	3.15
24	5.40	9.50	8.00	5.30	4.85	3.20	1.50	1.10	1.05	1.85	.95	3.00
25	4.90	8.60	7.55	5.25	4.60	3.20	1.45	1.05	1.15	1.80	1.00	3.40
26	4.85	8.95	6.40	5.40	4.50	3.10	1.45	.95	1.30	1.70	1.10	3.80
27	4.85	20.05	11.10	8.50	4.10	3.05	1.40	.90	1.20	1.70	1.10	4.10
28	4.60	14.65	15.00	8.70	3.90	3.30	1.30	.90	1.20	1.60	1.05	4.40
29	4.50	.....	18.70	7.75	3.85	4.15	3.80	.85	1.20	1.65	1.00	3.05
30	4.60	.....	14.10	7.10	3.80	4.05	3.00	.80	1.20	1.70	.85	2.90
31	4.50	.....	9.05	.....	4.30	.....	2.25	2.60	.....	1.60	.....	2.85

FRENCH BROAD RIVER AT ASHEVILLE, NORTH CAROLINA.

French Broad River rises in the western part of North Carolina, and flows in a general northwesterly direction into Tennessee. It joins Holston River just above Knoxville to form the Tennessee. The watershed is for the most part mountainous and covered with a heavy growth of timber. There are water powers capable of development at a number of places on the French Broad. The drainage area is mapped on the Asheville, Mount Mitchell, Pisgah, and Saluda atlas sheets. Measurements of flow have been made at Asheville, North Carolina. This station, described in the Eighteenth Annual

Report, Part IV, page 116, was established by Cyrus C. Babb in September, 1895, and is located at the Bingham School iron highway bridge, 3 miles west of Asheville, North Carolina, and is reached by an electric car line from Asheville. The Swannanoa River joins the French Broad 3 miles above the station. The zero of the rod of the wire gage is opposite the east edge of the fifth upright, first span from east, upper side. When the gage height is 3.22 feet, water surface is 17.18 feet below top of the lower end of the second floor beam, first span from the east. The gage was last verified on October 27, 1899. The initial point for soundings is on the right bank at the end of the first span of the bridge. Both banks may overflow in very high water. The current is swift, the channel straight, rocky, and reasonably permanent. The observer is J. M. Taylor, a carpenter at Asheville, North Carolina. Records of measurements may be found as follows: 1895–97, Nineteenth Annual Report, Part IV, page 257; 1898, Twentieth Annual Report, Part IV, page 205.

The following measurements were made by E. W. Myers and R. E. Shuford during 1899:

February 25, gage height, 4.30 feet; discharge, 2,810 second-feet.
June 16, gage height, 3.03 feet; discharge, 2,359 second-feet.
September 30, gage height, 1.94 feet; discharge, 714 second-feet.
October 27, gage height, 1.95 feet; discharge, 815 second-feet.
November 30, gage height, 2.12 feet; discharge, 1,043 second-feet.

Daily gage height, in feet, of French Broad River at Asheville, North Carolina, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.60	3.60	6.80	5.25	4.20	2.90	2.40	2.45	3.10	1.80	2.30	2.23
2	4.20	3.55	6.40	5.20	4.15	2.80	2.43	2.30	3.05	1.83	2.30	2.15
3	3.90	4.65	5.60	5.80	4.17	2.73	2.50	2.23	3.00	1.85	2.20	2.15
4	3.80	8.20	4.40	5.50	4.15	2.70	2.45	2.20	2.80	1.90	2.15	2.20
5	3.90	8.00	4.20	5.10	4.20	2.73	2.45	2.10	2.60	1.90	2.13	2.17
6	3.95	7.03	4.30	5.40	4.30	2.65	2.47	2.00	2.30	2.00	2.10	2.15
7	4.20	7.00	4.35	5.85	4.40	2.53	2.45	2.03	2.10	2.05	2.07	2.13
8	4.70	6.50	4.35	5.80	4.30	2.50	2.40	2.50	3.50	2.65	2.05	2.11
9	4.65	5.50	4.30	5.70	4.30	2.57	2.40	2.70	2.60	2.40	2.03	2.05
10	4.50	5.00	4.25	5.80	4.20	2.63	2.37	3.00	2.50	2.30	2.00	2.15
11	4.40	4.80	4.30	5.90	4.35	2.70	2.35	3.50	2.35	2.25	2.00	3.40
12	4.20	4.70	4.30	6.45	4.60	2.73	2.35	2.45	2.20	2.20	2.20	6.35
13	4.10	4.50	5.00	6.45	4.55	2.65	2.30	2.20	2.15	2.13	1.97	6.13
14	4.03	4.40	8.50	5.60	4.40	2.53	2.23	2.25	2.10	2.05	1.95	5.20
15	4.40	4.30	11.50	4.50	4.30	2.50	2.20	2.27	2.10	2.65	1.93	3.70
16	4.40	5.60	9.00	4.80	4.20	2.57	2.15	2.23	2.10	2.40	1.95	2.77
17	4.35	5.40	7.60	4.60	4.00	2.63	2.40	2.10	2.10	2.30	2.00	2.85
18	4.30	5.25	5.50	4.50	3.80	2.83	2.45	2.05	2.15	2.25	2.00	2.75
19	4.25	5.20	11.25	4.45	3.70	2.80	2.37	2.03	2.23	2.20	2.13	2.70
20	4.10	5.00	10.00	4.35	3.60	2.80	2.27	2.03	2.20	2.10	2.10	2.67
21	3.70	4.15	7.50	4.30	4.40	2.70	2.23	2.00	2.10	2.05	2.07	2.60
22	3.65	4.30	6.70	4.20	4.30	2.65	2.15	2.00	1.90	2.07	2.05	2.55
23	3.60	4.50	6.05	4.40	4.20	2.60	2.20	1.97	1.85	2.10	2.03	3.40
24	3.70	4.40	5.70	4.50	4.00	2.55	2.20	1.95	1.83	2.10	2.00	3.93
25	4.05	4.30	5.40	4.60	3.80	2.47	2.15	1.93	1.90	2.07	2.00	3.80
26	4.03	4.40	5.25	4.70	3.70	2.65	3.00	2.00	2.15	2.05	2.15	3.53
27	4.00	8.80	5.60	4.50	3.60	2.85	3.15	2.10	2.10	2.03	2.30	2.10
28	3.80	7.75	5.25	4.40	2.85	2.95	3.00	2.50	2.15	2.00	2.40	2.70
29	3.75	.....	5.33	4.30	2.80	2.80	2.80	2.60	1.85	2.05	2.37	2.65
30	3.70	.....	5.40	4.25	2.75	2.50	2.50	2.80	1.80	2.13	2.35	2.60
31	3.65	.....	5.35	.....	3.00	.....	2.43	3.85	.....	2.25	.....	2.57

TUCKASEGEE RIVER AT BRYSON, NORTH CAROLINA.

This river rises in the southwestern part of North Carolina, at the base of Tennessee Ridge, which separates Jackson and Transylvania counties. It flows in a northwesterly direction, emptying into the Little Tennessee River at Bushnell, North Carolina. Measurements of discharge are made at Bryson, 2 miles below the mouth of Newton Mill Creek. The drainage area is 609 square miles, largely of a rough and mountainous nature, covered with forest growth, and is mapped on the Cowee, Pisgah, and Mount Guyot atlas sheets. The old station, described in the Eighteenth Annual Report, Part IV, page 116, was located on the Southern Railway bridge about 3 miles above Bryson, North Carolina, and just below Governor Island post-office, and was abandoned March 25, 1897, because the section was poor. A new station was established by A. P. Davis November 7, 1897, at the highway bridge in the town of Bryson, North Carolina. The gage is bolted to the north pier, lower side, and can be read from the bridge. The initial point of sounding is at the south end of upstream hand rail. The channel is straight, but obstructed by the remnants of two old piers. The current is sluggish, the river bed muddy and fairly constant. The observer is H. H. Welch, a carpenter at Bryson, North Carolina. Results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 117; 1897, Nineteenth Annual Report, Part IV, page 257; 1898, Twentieth Annual Report, Part IV, page 206. The following measurements were made by E. W. Myers and R. E. Shuford in 1899:

Measurements of Tuckasegee River at Bryson, North Carolina.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Sec.-feet.*	1899.	*Feet.*	*Sec.-feet.*
Feb. 26	7.00	19,160	Oct. 28	1.10	404
June 17	2.00	1,216	Do	1.10	460
June 19	1.80	712	Dec. 5	1.20	479
Sept. 20	1.25	376	Dec. 28	1.70	1,010
Do	1.25	369			

Daily gage height, in feet, of Tuckasegee River at Bryson, North Carolina, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.50	2.05	3.20	3.40	2.30	1.80	1.50	1.40	1.40	1.00	1.00	1.50
2	2.20	1.85	3.00	3.05	2.30	1.80	1.50	1.40	1.40	1.00	1.00	1.40
3	2.05	3.00	2.25	3.50	2.50	2.00	1.50	1.40	1.35	1.00	1.80	1.40
4	2.20	9.00	3.30	3.20	2.60	1.70	1.50	1.40	1.30	1.00	1.70	1.20
5	2.60	.....	3.50	3.10	2.60	1.70	1.50	1.40	1.30	1.00	1.20	1.20
6	3.00	7.50	3.40	3.10	3.00	1.70	1.80	1.30	1.30	1.00	1.15	1.20
7	2.60	7.00	3.25	3.10	3.00	1.70	1.80	1.30	1.20	1.00	1.05	1.20
8	2.55	5.30	3.00	3.00	2.90	1.70	1.70	1.30	1.20	2.00	1.05	1.20
9	2.50	3.50	2.95	3.60	2.85	1.70	1.60	1.30	1.20	1.50	1.00	1.50
10	2.80	3.00	2.80	3.20	2.60	1.80	1.60	1.40	1.20	1.40	1.00	1.30
11	2.30	3.20	2.80	3.00	2.60	1.80	1.50	1.40	1.20	1.40	1.00	1.50
12	(a)	3.00	2.65	3.00	2.35	3.50	1.40	1.40	1.20	1.30	1.00	6.50
13	(a)	2.80	2.60	2.90	2.30	2.80	1.30	1.40	1.20	1.25	1.00	2.90
14	2.60	2.80	3.40	2.90	2.20	2.20	1.30	1.40	1.20	1.10	1.00	2.00
15	2.30	2.70	9.60	2.85	2.20	2.10	1.30	1.30	1.20	1.00	1.00	1.65
16	2.20	2.70	6.50	2.80	2.25	2.00	1.30	1.30	1.20	1.00	1.00	1.50
17	2.20	2.70	4.80	2.60	2.20	2.00	1.50	1.30	1.15	1.00	1.00	1.30
18	2.20	2.60	4.90	2.60	2.25	2.00	1.30	1.30	1.15	1.00	1.00	1.30
19	2.10	2.50	11.00	2.55	2.25	1.80	1.30	1.30	1.10	1.00	1.00	1.90
20	2.10	2.50	5.80	2.50	2.20	1.70	1.30	1.20	1.25	2.00	1.05	1.50
21	2.05	2.50	4.60	2.50	2.10	1.70	1.40	1.20	1.05	1.15	1.50	1.50
22	2.00	2.45	4.80	2.45	2.00	1.60	1.40	1.20	1.00	1.10	1.50	1.50
23	2.00	2.40	4.30	2.40	2.00	1.60	1.50	1.20	1.00	1.10	1.30	1.50
24	2.20	2.35	3.70	3.00	2.00	1.60	1.50	1.20	1.00	1.10	1.20	1.90
25	2.05	2.30	3.60	2.90	2.00	1.50	1.50	1.20	1.00	1.10	1.20	1.90
26	2.00	3.40	3.60	2.80	1.90	1.80	1.50	1.20	1.00	1.10	1.20	1.90
27	2.00	7.00	4.00	2.80	1.90	1.70	1.50	1.20	1.00	1.05	1.20	1.80
28	1.95	3.50	3.60	2.60	1.90	1.60	2.00	1.30	1.00	1.05	1.50	1.70
29	1.90	.....	3.50	2.50	1.80	1.60	2.00	1.35	1.00	1.05	1.45	1.70
30	1.80	.....	3.40	2.40	1.80	1.60	1.60	1.50	1.00	1.00	1.30	1.50
31	2.00	.....	4.00	.....	1.80	.....	1.50	1.50	.....	1.00	.....	1.50

a River frozen.

LITTLE TENNESSEE RIVER AT JUDSON, NORTH CAROLINA.

This river rises in the mountains between North Carolina and Georgia, and flows in a northwesterly direction, emptying into Tennessee River at Lenoir, Tennessee. Measurements of flow are made at Judson, North Carolina, below the mouth of Sawyer Branch. The area drained is 682 square miles, which is largely mountainous and covered with a forest growth. It is mapped on the Nantahala, Cowee, and Walhalla atlas sheets. The station, as described in the Eighteenth Annual Report, Part IV, page 117, was established by E. W. Myers in June, 1896. It is located on the Southern Railway bridge about one-fourth of a mile from Judson, North Carolina. The river is straight for several hundred yards above and below the station; the bottom rocky and very rough on the west side and sandy on the east side. The current is swift and considerably obstructed by two old piers. The section is constant, but not a good one for measurements. The observer is R. C. Sawyer, a farmer at Judson, North Carolina. Records of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 117; 1897, Nineteenth Annual Report, Part IV, page 256; 1898, Twentieth Annual Report, Part IV, page 207. The following measurements were made by E. W. Myers and R. E. Shuford during 1899:

February 27, gage height, 10.25 feet; discharge, 21,880 second-feet.
June 20, gage height, 3.30 feet; discharge, 1,491 second-feet.
September 21, gage height, 2.23 feet; discharge, 339 second-feet.
September 27, gage height, 2.65 feet; discharge, 721 second-feet.
October 29, gage height, 2.84 feet; discharge, 896 second-feet.
December 6, gage height, 2.75 feet; discharge, 758 second-feet.

Daily gage height, in feet, of Little Tennessee River at Judson, North Carolina, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.52	3.56	4.82	4.78	3.78	2.38	3.14	3.70	4.32	2.48	2.48	2.72
2	3.59	3.59	4.39	4.50	3.76	2.47	3.40	3.68	4.21	2.46	2.49	2.72
3	3.59	4.98	3.98	3.99	3.80	2.40	3.33	3.66	3.17	2.46	2.40	2.70
4	3.57	11.38	3.74	3.82	3.92	2.37	3.30	3.64	3.80	2.45	2.41	2.70
5	3.58	10.58	3.72	3.81	5.68	2.38	3.27	3.62	3.81	2.42	2.72	2.70
6	3.52	9.72	3.64	3.80	4.98	2.34	3.28	3.58	3.70	2.39	2.74	2.58
7	4.23	11.40	3.64	3.78	4.80	2.31	4.42	3.47	2.91	2.39	2.69	2.59
8	4.23	9.58	3.68	3.72	3.91	2.30	3.90	3.28	2.46	3.71	2.68	2.52
9	3.98	8.56	3.67	3.72	3.90	2.29	3.18	2.71	2.33	5.58	2.64	2.50
10	3.92	7.51	3.61	3.70	3.82	2.29	3.10	2.70	2.32	4.31	2.64	2.62
11	3.84	5.32	3.61	3.68	3.71	2.27	2.90	4.98	2.32	3.72	2.63	2.62
12	3.84	5.32	3.62	3.69	3.70	2.91	2.71	4.57	2.28	3.20	2.62	2.60
13	3.80	4.58	3.64	3.49	3.68	6.71	2.71	3.38	2.27	2.58	2.62	2.70
14	3.71	3.72	9.55	3.48	3.60	6.70	2.70	2.92	2.25	2.51	2.62	8.40
15	3.70	3.71	7.42	3.46	3.62	5.82	2.68	2.88	2.25	2.50	2.64	6.50
16	3.69	3.70	8.93	3.48	3.80	5.40	2.69	2.88	2.24	2.50	2.63	4.51
17	3.68	3.68	6.81	3.52	3.82	3.58	3.48	2.64	2.22	2.48	2.58	3.92
18	3.69	3.68	4.58	3.52	3.71	3.41	3.30	2.63	2.25	2.49	2.59	2.94
19	3.69	3.72	13.00	3.51	3.74	3.40	3.10	2.60	2.28	2.52	2.57	2.94
20	3.69	3.74	12.00	3.48	3.78	2.56	2.93	2.60	2.28	2.52	2.57	2.90
21	3.66	3.74	8.55	3.49	3.52	2.58	2.84	2.48	2.23	2.57	2.49	2.53
22	3.68	3.70	6.54	3.61	2.90	2.47	3.91	2.42	2.20	2.60	2.54	2.52
23	3.67	3.69	4.88	3.60	2.80	2.75	4.28	2.41	2.21	2.60	2.70	2.41
24	3.67	3.68	4.32	3.72	2.50	2.70	4.20	2.41	2.21	2.50	2.71	2.40
25	3.69	3.60	4.28	3.72	2.47	3.15	3.90	2.40	2.26	2.50	2.77	2.42
26	3.58	3.65	3.92	3.70	2.46	3.10	3.90	2.39	2.65	2.50	2.89	2.42
27	3.52	10.25	4.78	3.78	2.30	3.00	3.91	2.38	2.50	2.50	3.42	2.43
28	3.59	6.72	4.74	3.74	2.31	3.31	3.88	2.37	2.41	2.60	3.50	2.41
29	3.58	.....	5.70	3.79	2.36	3.30	3.86	2.37	2.41	2.58	2.98	2.42
30	3.59	.....	5.90	3.76	3.36	3.00	3.86	2.24	2.40	2.57	2.90	2.42
31	3.57	.....	5.60	.....	2.84	.....	3.71	2.26	.....	2.57	.....	2.39

HIWASSEE RIVER AT MURPHY, NORTH CAROLINA.

Hiwassee River rises in the northern part of Georgia and flows through the southwestern corner of North Carolina into Tennessee, where it empties into Tennessee River. The watershed is broken and mountainous for the most part and well covered with forest. The area drained is 410 square miles, and is mapped on the Murphy, Nantahala, and Dahlonega atlas sheets. The river is measured at two places, Murphy, North Carolina, and Charleston, Tennessee, 17 miles above its mouth. The station at Murphy, described in the Eighteenth Annual Report, Part IV, page 117, is located on the highway bridge crossing the river at Murphy, North Carolina, one-half mile above Valley River, and was established by E. W. Myers July 26, 1896. The wire gage was last verified on December 29, 1899. The length of the gage is 29.10 feet. The section here is a fairly good one, though somewhat obstructed by the remains of two old piers directly under the present bridge. The course of the stream is straight for several hundred yards above and below the bridge, and the current fairly rapid. The bottom is hard and rocky and not subject to any decided change by high water. The observer is M. L. Brittain, Murphy, North Carolina. The results of measurements may be found as follows: 1896–97, Nineteenth Annual Report, Part IV, page 269; 1898, Twen-

tieth Annual Report, Part IV, page 209. The following measurements were made by E. W. Myers and R. E. Shuford in 1899:

February 28, gage height, 7.50 feet; discharge, 2,150 second-feet.
June 23, gage height, 5.17 feet; discharge, 400 second-feet.
June 23, gage height, 5.30 feet; discharge, 436 second-feet.
September 28, gage height, 4.93 feet; discharge, 304 second-feet.
September 28, gage height, 5.00 feet; discharge, 345 second-feet.
December 7, gage height, 5.10 feet; discharge, 317 second-feet.
December 29, gage height, 5.50 feet; discharge, 613 second-feet.

Daily gage height, in feet, of Hiwassee River at Murphy, North Carolina, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	5.80	5.60	6.90	6.80	5.85	5.30	.....	5.30	5.40	4.90	4.85	5.10
2	5.70	5.70	6.60	6.60	5.82	5.30	.....	5.20	5.25	4.80	4.90	5.35
3	5.70	5.70	6.70	6.50	5.80	5.30	.....	5.20	5.50	4.85	4.90	5.10
4	5.65	14.00	6.32	7.20	5.80	5.25	.....	5.15	5.30	4.75	4.90	5.10
5	5.60	9.60	7.40	6.55	6.10	5.25	.....	5.12	5.20	4.80	4.90	5.10
6	5.70	9.45	6.75	6.50	5.80	5.25	.....	5.20	5.10	4.90	4.90	5.02
7	6.30	9.90	6.50	6.55	5.85	5.10	.....	5.20	5.10	4.90	4.90	5.00
8	6.00	7.85	6.40	6.70	5.70	5.10	.....	5.20	5.15	5.70	4.90	5.10
9	5.90	7.20	6.40	6.60	5.70	5.20	5.20	5.12	5.05	5.15	4.90	5.05
10	5.80	6.75	6.30	6.50	5.70	5.15	5.10	5.15	5.00	5.00	4.90	5.10
11	5.80	6.60	6.20	6.40	5.62	5.10	5.10	5.15	5.20	5.02	4.90	5.10
12	5.80	6.55	6.10	6.30	5.62	5.82	5.05	5.10	5.10	5.00	4.85	9.10
13	5.70	6.30	6.10	6.20	5.60	5.80	5.00	5.10	5.00	4.90	4.85	6.30
14	5.70	6.40	6.75	6.20	5.55	5.50	5.00	5.05	5.00	4.80	4.90	5.82
15	5.75	6.40	10.80	6.10	5.60	5.35	5.00	5.20	5.00	5.00	4.90	5.70
16	5.75	6.30	8.75	6.10	5.50	5.25	5.00	5.32	4.90	5.00	4.90	5.50
17	5.75	6.25	7.50	6.05	5.50	5.30	5.10	5.20	5.00	5.00	4.90	5.40
18	5.70	6.25	7.10	6.00	5.50	5.20	5.30	5.10	5.00	4.95	4.90	5.40
19	5.70	6.00	18.40	6.00	5.60	5.20	5.20	5.00	5.00	5.10	4.85	5.30
20	5.70	6.10	8.70	6.00	5.50	5.15	5.10	5.00	5.10	5.00	4.85	5.50
21	5.70	6.10	7.60	6.00	5.45	5.10	5.30	5.00	5.00	5.00	4.90	5.40
22	5.60	6.10	7.20	5.90	5.40	5.10	5.30	5.00	5.00	4.90	4.90	5.35
23	5.60	6.00	8.15	5.90	5 40	5.10	5.30	5.00	5.00	4.90	5.40	5.30
24	5.52	5.92	7.00	5.90	5.42	4.85	5.20	5.00	5.00	4.90	5.12	6.30
25	5.65	6.10	6.80	6.70	5.40	4.95	5.20	5.10	5.00	4.90	5.10	5.70
26	5.60	6.00	6.60	6.10	5.40	5.05	6.80	5.05	5.00	4.90	5.75	5.60
27	5.60	9.10	6.52	6.00	5.35	5.00	5.75	5.25	5.02	4.90	5.40	5.50
28	5.60	7.30	6.50	6.00	5.35	5.00	5.90	5.45	5.00	5.00	5.30	5.55
29	5.50	.....	6.90	5.90	5.32	5.00	.....	5.10	5.00	5.10	5.20	5.50
30	5.50	.....	6.70	5.90	5.32	5.00	.....	5.10	4.88	4.90	5.10	5.35
31	5.90	.....	7.80	.....	5.30	.....	.....	5.70	.....	5.00	.....	5.40

No readings July 1 to 9; gage broken.

HIWASSEE RIVER AT CHARLESTON, TENNESSEE.

The gaging station on this river is located at the bridge of the Southern Railway 600 feet from the depot in the town of Charleston, Tennessee. It is 17 miles above the mouth of the river and 53 miles above Chattanooga, Tennessee. The drainage area is mapped on the Cleveland, Murphy, Ellijay, Nantahala, Dahlonega, Dalton, Loudon, and Kingston atlas sheets. This station was originally established by the United States Engineer Corps, but is now maintained as a half-year station by the United States Weather Bureau, gage heights being kept from November 1 to April 31, inclusive. The gage rod is fastened to the downstream end of the south pier of the bridge, 125 feet from the shore. It is painted white and marked in feet and tenths. The bench mark is a cross cut in the top surface of the upper corner stone of the

pier, and is 35.00 feet above the zero of the gage. The greatest height recorded at this point was on March 31, 1886, when the gage read 32.2 feet. The danger line is placed at 22 feet. The railroad bridge is an iron 3-span bridge, with a total length of 390 feet. There are embankments at each end which confine the water, even at the highest stages, within the banks. The observer is J. M. Bates, Charleston, Tennessee. The following measurements were made by Max Hall in 1899:

May 6, gage height, 3.65 feet; discharge, 6,684 second-feet.
May 25, gage height, 2.05 feet; discharge, 3,730 second-feet.
September 16, gage height, 0.35 foot; discharge, 1,366 second-feet.
October 27, gage height, 0.20 foot; discharge, 1,194 second-feet.

Daily gage height, in feet, of Hiwassee River at Charleston, Tennessee, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	Nov.	Dec.
1	2.60	4.30	7.20	9.40	0.50	1.00
2	2.80	3.40	5.90	7.20	.40	.80
3	2.40	3.10	5.30	6.10	.40	1.20
4	2.30	16.00	5.30	6.40	.40	1.00
5	2.30	21.60	7.30	7.90	.40	.80
6	4.00	18.60	8.90	6.50	.30	.70
7	8.30	22.40	8.10	6.30	.30	.70
8	6.70	20.90	7.50	11.00	.30	.60
9	4.90	16.50	5.60	7.80	.30	.60
10	3.90	13.50	4.50	7.10	.30	.60
11	3.40	8.90	4.30	6.00	.30	.60
12	3.50	5.90	4.00	5.60	.30	3.00
13	3.10	5.00	3.90	5.30	.30	7.00
14	2.90	3.70	5.70	5.00	.30	2.90
15	3.00	4.30	24.20	4.80	.30	2.10
16	2.90	4.80	27.30	4.60	.50	1.80
17	3.20	6.90	20.00	4.40	.50	1.40
18	3.30	5.60	14.40	4.10	.40	1.30
19	3.00	5.90	24.00	4.00	.40	1.30
20	2.80	5.30	27.60	4.00	.30	1.80
21	2.60	4.70	19.90	3.90	.30	2.00
22	2.50	4.60	16.60	3.70	.30	1.50
23	2.40	4.60	16.00	3.50	.70	1.40
24	2.40	4.20	13.00	4.50	1.70	3.20
25	2.70	3.90	8.70	4.60	1.00	3.70
26	2.70	3.70	7.60	6.00	.90	2.50
27	2.40	7.50	7.00	4.50	1.70	2.00
28	2.30	11.50	7.50	4.00	1.50	1.90
29	2.20	.....	10.60	3.70	1.20	2.00
30	2.20	.....	8.60	3.60	1.00	1.70
31	2.40	.....	8.00	.....	.....	1.10

No readings May 1 to October 31.

A measurement of Hiwassee River at Reliance, Tennessee, was made by Max Hall, October 25, 1899: Gage height, 2.60 feet; discharge, 607 second-feet.

TOCCOA RIVER AT BLUERIDGE, GEORGIA.

This stream has its source on the northern slopes of the Blue Ridge Mountains, in Georgia, and flows northwesterly into Hiwassee River. The area is covered with a fine growth of oak, hickory, and other hard woods, and is mapped on the Ellijay and Dahlonega atlas sheets. The station, established by B. M. Hall on November 25, 1898, is located at the Morganton bridge, about 4 miles east of the town of Blueridge, Georgia. The gage is a 14-foot rod, in two 7-foot sections, nailed to a

tree on the right bank just below the bridge. It is graduated to feet and tenths, and is set to conform to bench marks which were established October 15, 1896, and October 26, 1898. The measurements during 1896 were made at the railroad bridge about 3 miles below, but are referred to the present gage by comparison of the bench marks at the two bridges. The bench mark at Morganton bridge is on the top of the bridge floor, on the downstream side, 50 feet from the initial point, and is 18.00 feet above zero of gage. This bridge is a wooden, queen-post, open bridge, in three spans, with a total length between abutments of 153 feet. The width of the river, including the two piers, at ordinary stages is 143 feet between banks, the three channels being 50, 38, and 33 feet. The observer is M. V. Pressley, a mail carrier who crosses the bridge twice daily, except on Sundays; no readings are had on this day, but figures have been interpolated. The following measurements were made by B. M. Hall and Max Hall during 1899:

April 28, gage height, 3.50 feet; discharge, 1,141 second-feet.
June 16, gage height, 2.70 feet; discharge, 522 second-feet.
September 18, gage height, 1.93 feet; discharge, 242 second-feet.
October 24, gage height, 1.90 feet; discharge, 223 second-feet.

Daily gage height, in feet, of Toccoa River at Blueridge, Georgia, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.10	3.20	4.30	4.20	3.70	3.00	2.50	2.60	2.80	2.00	2.10	2.40
2	3.00	3.20	4.00	3.60	3.50	2.10	2.45	2.60	2.40	2.00	2.00	2.20
3	2.90	3.30	4.10	3.11	3.50	2.10	2.40	2.50	2.40	1.90	2.00	2.10
4	2.90	5.40	4.10	4.60	3.40	2.20	2.40	2.50	2.50	1.90	2.00	2.10
5	2.10	6.70	4.00	4.40	3.10	3.00	2.50	2.50	2.40	1.90	2.00	2.10
6	3.02	8.90	4.00	3.90	3.60	2.90	2.80	2.50	2.40	2.00	2.00	2.00
7	3.04	6.10	3.80	4.50	3.40	2.90	2.70	2.50	2.30	3.00	2.00	2.00
8	3.08	5.50	3.70	4.80	3.20	2.90	2.80	2.40	2.30	2.80	2.10	2.00
9	3.10	5.00	3.60	4.00	3.20	2.70	2.75	2.30	2.30	2.60	2.10	2.00
10	3.10	4.00	3.10	4.00	3.10	2.70	2.75	2.30	2.50	2.30	2.10	2.50
11	3.20	3.70	3.00	3.10	3.00	2.70	2.70	2.30	2.60	2.10	2.10	3.60
12	3.00	3.80	3.50	3.90	3.00	3.40	2.70	2.60	2.50	2.00	2.10	3.50
13	3.00	3.90	4.00	3.80	3.00	3.20	2.80	3.40	2.30	2.00	2.00	3.30
14	3.10	4.00	4.00	3.70	3.00	3.00	2.70	3.40	2.30	2.00	2.00	2.90
15	3.10	4.00	4.90	3.70	3.00	2.10	2.60	3.40	2.20	2.00	2.10	2.80
16	3.10	4.10	6.00	3.60	3.00	2.70	2.40	3.20	2.20	2.00	2.10	2.50
17	3.20	3.10	4.40	3.60	3.00	2.60	2.40	2.40	2.10	2.00	2.00	2.40
18	3.10	3.30	4.00	3.60	3.00	2.60	2.80	2.40	2.30	2.00	2.00	2.30
19	3.00	3.40	4.50	3.60	3.30	2.60	2.70	2.40	2.30	2.00	2.00	2.60
20	3.00	3.60	5.00	3.60	3.00	2.60	2.70	2.20	2.00	2.00	2.00	2.60
21	2.10	3.50	4.80	3.60	3.20	2.50	2.80	2.20	2.00	2.00	2.00	2.50
22	3.00	3.60	4.60	3.60	3.20	2.45	2.80	2.20	2.00	2.00	2.00	2.40
23	3.80	3.50	5.60	3.80	3.10	2.60	2.60	2.30	2.00	2.00	2.00	2.50
24	3.10	3.40	5.00	4.00	3.10	2.10	2.50	2.20	2.00	2.00	2.00	------
25	3.20	3.40	4.50	5.30	3.10	2.40	2.80	2.30	2.00	2.00	2.00	------
26	3.10	4.00	4.20	4.10	3.10	2.70	2.80	2.20	2.00	2.00	2.30	------
27	2.10	5.80	4.00	4.60	3.10	2.90	3.90	2.40	2.00	2.00	2.60	------
28	2.10	4.90	4.00	3.10	3.00	2.85	3.60	2.60	2.00	2.00	2.30	------
29	2.09	------	4.00	3.00	3.00	2.70	2.80	2.50	2.00	2.20	3.20	------
30	2.80	------	4.00	3.30	3.10	2.60	2.80	2.60	2.00	2.40	3.10	------
31	4.00	------	4.80	------	3.11	------	2.80	2.70	------	2.20	------	------

TENNESSEE RIVER AT KNOXVILLE, TENNESSEE.

This river is formed by the junction of French Broad and Holston rivers 4 miles above Knoxville. The drainage basin is mapped on Knoxville, Maynardsville, Morristown, Jonesville, Estillville, Bristol,

Abingdon, Tazewell, Pocahontas, Greenville, Asheville, Roan Mountain, Cranberry, Mount Guyot, Mount Mitchell, Morganton, Saluda, Pisgah, Cowee, and Wytheville atlas sheets. The station was originally established by the United States Weather Bureau, and was located at the old county highway bridge at Knoxville, which has lately been torn down. The new gage is situated at the Augusta and Knoxville Railroad bridge. The datum of the new gage is 0.6 of a foot higher than that of the old one, so that this amount has to be added to the new readings to make them conform to the old standard. This correction has been applied to the published heights of the Weather Bureau and of this Survey, both in the table of gage heights and in the list of discharge measurements. Measurements of discharge are made at the Cherokee highway bridge 2¼ miles below the gage, as there is at that point a better section for meter measurements. This bridge is a three-span iron bridge, and the width of water surface at low stages under it is 550 feet. The bridge is about 80 feet above low water. The following measurements were made by Max Hall during 1899:

May 4, gage height, 1.90 feet; discharge, 12,810 second-feet.
May 25, gage height, 1.70 feet; discharge, 10,134 second-feet.
September 16, gage height, 0.10 foot; discharge, 3,912 second-feet.
October 26, gage height, —0.60 foot; discharge, 2,728 second-feet.

Daily gage height, in feet, of Tennessee River at Knoxville, Tennessee, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	(a)	1.20	9.20	8.00	2.30	1.50	1.20	1.00	0.80	—0.10	—0.20	0.30
2	(a)	1.20	6.80	6.60	2.20	1.10	.90	.80	1.60	— .20	+ .40	.30
3	(a)	1.40	6.40	5.60	2.00	1.70	.60	.70	1.40	— .30	.50	.30
4	(a)	8.60	14.00	5.80	2.00	1.60	.40	.60	.80	— .30	.50	.40
5	(a)	16.70	14.40	8.20	2.40	1.40	.20	.40	.60	— .40	.50	.30
6	(a)	18.70	19.20	7.60	2.60	1.20	.40	.30	.40	— .40	.40	.30
7	(a)	22.50	16.40	6.00	3.80	1.10	.30	.20	.30	— .50	.30	.10
8	(a)	22.20	9.00	5.90	4.40	.90	.30	.20	.30	— .30	.10	.10
9	(a)	16.00	6.70	6.50	5.40	.90	.40	.20	.30	— .20	.00	.00
10	(a)	9.40	6.10	7.30	5.20	1.10	.40	.30	.30	— .60	— .10	— .10
11	(a)	6.00	5.10	6.20	4.40	1.20	.40	.30	.40	+ .80	— .20	— .20
12	(a)	5.00	4.60	5.20	4.60	1.40	.50	.70	.70	— .70	— .20	.00
13	(a)	4.20	4.20	4.80	4.30	1.70	.30	.80	.60	.40	— .30	4.60
14	(a)	3.60	3.90	4.50	4.40	3.00	.20	.80	.40	.30	— .30	5.30
15	(a)	2.00	11.50	4.00	4.80	3.10	.10	.60	.30	.20	— .40	4.90
16	(a)	2.40	20.40	3.80	4.80	3.70	.00	.60	.20	.10	— .50	3.80
17	2.40	3.40	17.40	3.50	3.00	2.40	.00	.50	.10	.00	— .50	2.60
18	2.50	7.00	11.00	3.20	2.40	2.00	.10	.30	.00	— .10	— .60	1.90
19	2.40	6.60	18.00	2.90	2.20	1.60	.20	.20	— .10	— .10	— .60	1.80
20	2.20	5.70	28.00	2.80	2.10	1.40	.40	.10	.00	— .20	— .60	1.80
21	2.10	4.80	25.40	2.60	1.90	1.20	.40	.00	.20	— .20	— .70	1.60
22	1.80	4.30	13.60	2.50	1.80	1.00	.40	.10	.50	— .30	— .70	1.90
23	1.60	4.40	10.10	2.30	1.80	.90	.30	.20	.40	— .30	— .70	1.80
24	1.50	4.40	7.80	2.20	1.70	.70	.20	.30	.20	— .40	— .60	2.10
25	1.50	3.90	7.00	2.40	1.70	.80	.30	.40	.00	— .50	— .50	3.40
26	1.60	3.50	6.50	2.60	1.60	1.20	.30	.40	.00	— .50	— .50	3.70
27	1.60	5.20	7.60	3.00	1.40	1.00	1.40	.50	.20	— .60	— .40	3.20
28	1.50	9.40	9.20	2.70	1.30	1.10	1.30	.60	.20	— .60	— .20	2.50
29	1.30	.....	12.20	2.60	1.20	1.60	2.10	.60	.10	— .60	+ .20	2.20
30	1.20	.....	12.10	2.50	1.20	1.40	2.60	.00	.00	— .40	.30	1.70
31	1.20	.....	10.40	.....	1.30	.....	1.40	.00	.....	— .40	.....	1.70

a January 1 to 16, no readings; gage obstructed by false work of new bridge.

Clinch River, a tributary of Tennessee River, was measured at Clinton, Tennessee, on May 5, at a gage height of 7.55 feet, and showed a discharge of 5,220 second-feet.

TENNESSEE RIVER AT CHATTANOOGA, TENNESSEE.

This river, after passing Chattanooga, enters Alabama. It then makes a bend to the west and later to the north, returning to Tennessee. Flowing through this State and Kentucky, it empties into the Ohio 50 miles above Cairo. In 1879 a gage was established at Chattanooga, Tennessee, at the foot of Lookout street, just below Chattanooga Island, by the Signal Corps of the United States Army, which has been in charge of the Weather Bureau since July 1, 1891. The drainage area above this station is 21,382 square miles, and is mapped on Morristown, Greenville, Roan Mountain, London, Knoxville, Mount Guyot, Asheville, Murphy, Briceville, Standingstone, Wartburg, Pikeville, Maynardville, Cumberland Gap, Jonesville, Estillville, Bristol, Whitesburg, Grundy, Abingdon, Tazewell, Pocahontas, Wytheville, Cranberry, Morganton, Mount Mitchell, Saluda, Pisgah, Como, Nantahala, Walhalla, Dahlonega, Ellijay, Dalton, Cleveland, Ringgold, Kingston, and Chattanooga atlas sheets. The gage is on an inclined railroad iron for about 20 feet of its lower portion. Above this it is a vertical rod bolted to the rock bluff forming the river bank. The zero of the gage is 630.64 feet above sea level. Measurements are made from the Hamilton County steel highway bridge at the foot of Walnut street, a short distance below the gage. Gage heights are obtained from L. M. Prindell, United States Weather Bureau observer. Records of measurement may be found as follows: 1890 to 1895, Eighteenth Annual Report, Part IV, page 120; 1896–97, Nineteenth Annual Report, Part IV, page 261; 1898, Twentieth Annual Report, Part IV, page 210. The following measurements were made by Max Hall and others during 1899:

May 8, gage height, 6.71 feet; discharge, 37,770 second-feet.
May 26, gage height, 4.76 feet; discharge, 25,526 second-feet.
June 21, gage height, 4.15 feet; discharge, 21,391 second-feet.
September 15, gage height, 1.90 feet; discharge, 10,819 second-feet.
October 27, gage height, 0.80 foot; discharge, 6,566 second-feet.

East Chickamauga Creek, a tributary of the Tennessee, was measured at Anderson upper ford, 3 miles from Ringgold, Georgia, October 26, and gave a discharge of 35 second-feet.

Daily gage height, in feet, of Tennessee River at Chattanooga, Tennessee, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.75	5.70	19.25	22.80	7.60	4.15	3.45	4.20	2.20	1.20	1.10	1.70
2	4.95	5.65	17.60	19.50	7.10	4.25	3.30	3.55	2.35	1.10	1.10	1.70
3	5.30	5.60	15.15	14.90	6.70	4.40	3.05	3.05	2.80	1.05	1.05	1.70
4	5.80	10.70	14.15	12.95	6.30	4.85	2.80	2.75	3.05	.95	1.10	1.70
5	5.95	23.10	17.95	13.25	6.15	4.65	2.60	2.45	2.65	.90	1.50	1.80
6	7.25	30.45	24.50	14.70	7.10	4.25	2.60	2.45	2.25	.80	1.50	1.70
7	18.80	34.30	26.55	15.70	8.50	4.05	2.65	2.40	1.95	.85	1.50	1.60
8	18.40	36.95	27.60	18.05	9.35	3.75	3.05	2.40	1.80	1.00	1.45	1.50
9	17.35	38.25	27.70	17.75	10.00	3.55	2.90	2.25	1.60	1.15	1.35	1.40
10	17.15	36.75	16.15	15.70	10.70	3.40	2.60	2.10	1.80	1.60	1.20	1.40
11	13.85	30.30	11.85	14.20	11.15	3.90	2.55	2.10	1.70	1.80	1.15	1.60
12	10.50	19.35	10.60	12.90	10.40	4.30	2.45	2.00	2.00	1.85	1.10	5.20
13	9.15	12.15	9.55	11.65	9.60	5.25	2.30	2.00	1.80	1.70	1.00	6.45
14	8.10	9.50	11.20	10.70	9.30	5.80	2.20	2.25	2.00	1.65	1.00	7.40
15	7.55	8.50	24.55	10.00	9.55	6.45	2.15	2.65	1.85	1.40	1.00	7.15
16	7.30	7.55	34.25	9.40	9.20	6.10	1.95	2.65	1.65	1.25	1.00	6.20
17	7.40	7.95	36.90	8.75	8.70	6.40	1.90	2.40	1.45	1.15	1.00	5.20
18	7.45	9.55	36.15	8.40	7.75	6.20	1.80	2.30	1.35	1.15	1.00	4.25
19	7.25	11.30	35.85	8.00	6.90	5.25	1.90	2.15	1.20	1.10	1.00	3.85
20	7.00	12.65	37.05	7.55	6.40	4.70	2.05	1.90	1.05	1.10	.95	4.25
21	6.80	11.50	39.20	7.35	5.90	4.20	2.05	1.70	1.00	1.10	.85	4.40
22	6.45	10.65	40.00	7.05	5.60	3.75	2.40	1.60	1.05	1.10	.85	4.40
23	5.90	10.10	38.70	7.85	5.35	3.50	2.70	1.45	1.30	1.05	1.00	4.15
24	5.65	9.75	32.70	9.65	5.30	3.25	3.50	1.30	1.50	1.00	1.15	5.65
25	6.05	9.50	23.15	9.35	5.05	3.15	3.40	1.20	1.50	.95	1.30	6.15
26	6.35	9.20	16.30	10.75	4.80	3.00	3.00	1.20	1.45	.85	1.70	6.30
27	5.85	13.20	13.65	10.30	4.65	3.25	3.05	1.20	1.30	.80	1.80	5.85
28	5.75	18.45	13.95	9.20	4.40	3.65	3.65	1.25	1.20	.80	1.85	5.55
29	5.55	.....	17.30	8.35	4.30	3.50	4.25	1.50	1.25	.90	1.80	5.10
30	5.30	.....	21.20	7.75	4.20	3.30	4.25	1.85	1.30	1.00	1.75	4.65
31	5.30	.....	22.80	.....	4.25	.....	5.15	1.75	.....	1.05	.....	3.85

OLENTANGY RIVER AT COLUMBUS, OHIO.

This river rises in the north-central part of Ohio and flows in a southerly direction into the Scioto at Columbus. Its watershed is in general flat and for the most part cultivated. Systematic measurements were begun in Columbus on November 22, 1898, when the station at the Fifth avenue bridge was established by H. A. Pressey, Prof. C. N. Brown, and B. H. Flynn. The gagings are made on the upstream side of the bridge, the initial point being on the left bank. A wooden post, graduated to feet and tenths, was driven in the bed of the stream near the bridge as a gage, and referred to a scale cut in the face of the left abutment, from which high-water readings can be taken directly. The observations of river heights are made under the direction of Prof. C. N. Brown, of the Ohio State University. The students in civil engineering have for the last two years studied the rainfall and run-off of the basin of the Olentangy and Scioto rivers. A description of the watershed and the results of observations may be found in the Twentieth Annual Report, Part IV, page 215. The following measurements were made during 1899:

Measurements of Olentangy River at Columbus, Ohio.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Sec.-feet.*	1899.	*Feet.*	*Sec.-feet.*
Jan. 5	5.71	5,335	Mar. 25	3.25	1,717
Jan. 15	7.90	9,236	Mar. 27	3.15	1,546
Mar. 15	1.87	387	Mar. 31	3.67	2,221
Mar. 16	1.97	477	Apr. 6	1.70	326
Mar. 20	3.58	2,356	Apr. 17	1.45	180
Mar. 22	2.95	1,430	Apr. 22	1.33	126
Mar. 24	4.54	3,174	Sept. 16	0.90	5
Do	4.21	2,910			

Daily gage height, in feet, of Olentangy River at Columbus, Ohio, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.95	1.55	2.65	3.76	1.24	2.20	1.15	1.20	1.10	1.00	1.10	1.10
2	1.70	1.55	2.65	2.80	1.28	2.50	1.10	1.20	1.10	1.00	1.10	1.10
3	2.10	1.55	2.57	2.24	1.19	3.00	1.10	1.20	1.10	1.00	1.15	1.20
4	1.94	1.55	2.90	1.98	1.27	2.55	1.10	1.40	1.10	1.00	1.20	1.20
5	5.53	1.55	4.37	1.82	1.27	2.00	1.10	1.50	1.10	1.00	1.20	1.20
6	5.17	1.55	4.25	1.73	1.17	1.75	1.10	3.10	1.10	1.00	1.20	1.20
7	3.80	1.55	3.00	1.70	1.60	1.85	1.10	2.45	1.10	1.00	1.20	1.20
8	2.57	1.55	2.14	2.00	1.56	1.55	1.10	2.10	1.10	1.00	1.20	1.20
9	2.18	1.55	2.07	2.45	1.38	1.45	1.10	1.75	1.10	1.00	1.20	1.20
10	2.06	1.55	2.07	2.45	1.28	1.50	1.10	1.45	1.00	1.00	1.20	1.20
11	1.87	1.55	2.32	2.05	1.34	1.40	1.10	1.40	1.00	1.00	1.10	1.20
12	1.77	1.55	2.80	1.83	1.18	1.40	1.10	1.35	1.00	1.00	1.10	1.55
13	1.90	1.55	2.57	1.72	1.27	1.30	1.10	1.30	1.00	1.00	1.10	1.90
14	8.45	1.55	2.20	1.75	1.20	1.30	1.15	1.25	1.00	1.00	1.20	1.90
15	8.20	1.55	1.90	1.66	1.20	1.30	1.10	1.20	1.00	1.00	1.20	1.50
16	5.90	1.55	1.88	1.55	1.20	1.20	1.30	1.20	1.00	1.00	1.20	1.45
17	4.07	1.55	1.98	1.48	1.14	1.20	1.35	1.20	1.00	1.00	1.20	1.50
18	2.98	1.55	1.87	1.42	1.17	1.30	1.30	1.20	1.00	1.00	1.20	1.50
19	2.58	2.22	3.42	1.40	1.27	1.25	1.40	1.20	1.00	1.00	1.20	1.90
20	2.10	2.17	3.65	1.38	1.20	1.25	1.55	1.10	1.00	1.00	1.20	3.30
21	1.98	1.87	3.04	1.35	1.25	1.30	1.45	1.10	1.00	1.00	1.20	2.75
22	1.88	2.38	2.80	1.33	1.30	1.45	1.30	1.10	1.00	1.00	1.20	2.20
23	1.80	3.92	5.19	1.29	1.40	2.35	1.30	1.10	1.00	1.00	1.20	1.85
24	1.80	2.87	4.43	1.30	1.25	1.90	1.25	1.10	1.00	1.00	1.20	1.80
25	1.87	1.88	3.38	1.31	1.20	1.65	1.40	1.10	1.00	1.00	1.20	1.80
26	1.80	1.87	3.67	1.27	1.20	1.45	1.50	1.10	1.00	1.00	1.20	1.80
27	1.78	3.97	3.48	1.31	1.25	1.25	1.30	1.10	1.00	1.00	1.20	1.80
28	1.55	3.52	3.64	1.45	1.25	1.20	1.30	1.10	1.00	1.05	1.20	1.80
29	1.55	.....	3.73	1.35	1.35	1.20	1.20	1.10	1.00	1.10	1.15	1.80
30	1.55	.....	3.12	1.30	1.60	1.20	1.20	1.10	1.00	1.10	1.10	1.80
31	1.87	.....	3.64	.....	1.95	.....	1.20	1.10	.....	1.10	.....	1.80

SCIOTO RIVER AT COLUMBUS, OHIO.

This river drains the central portion of the State of Ohio, and flows in a general southerly direction into Ohio River near the city of Portsmouth. Its watershed is flat and highly cultivated above Columbus, while in the southern part it is hilly, with comparatively little cultivation. A description of the watershed and results of measurements may be found in the Twentieth Annual Report, Part IV, page 212. Systematic measurements were begun at Columbus November 22, 1898, when a station was established by H. A. Pressey, Prof. C. N. Brown, and B. H. Flynn. It is located at the Grandview avenue bridge in Columbus. The wire gage is located on the upstream side of the bridge, and is referred to a scale cut in the face of the left abutment, from which high-water readings can be taken directly. The river bed at the station is rocky. The banks are naturally low, but levees have been built on each side in order to prevent overflow; high water seldom reaches the top of the levees, but occasionally they are overflowed. The following measurements were made under the direction of Prof. C. N. Brown during 1899:

Measurements of Scioto River at Columbus, Ohio.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Sec.-feet.*	1899.	*Feet.*	*Sec.-feet.*
Jan. 15	19.50	13,895	Mar. 27	14.05	3,379
Jan. 20	13.00	2,291	Mar. 29	14.56	3,894
Mar. 6	15.50	5,367	Apr. 5	11.76	982
Mar. 8	13.35	2,457	Apr. 8	11.94	1,116
Mar. 9	12.89	1,996	Apr. 14	11.30	668
Mar. 17	11.61	942	Apr. 16	11.02	531
Mar. 20	14.05	3,271	Apr. 18	10.72	341
Mar. 22	14.30	3,905	Apr. 22	9.90	236
Mar. 24	15.00	4,526	Apr. 26	9.80	208
Do	14.57	4,050	Sept. 16	9.10	23
Mar. 25	14.58	3,919			

Daily gage height, in feet, of Scioto River at Columbus, Ohio, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	11.25	10.65	13.80	14.15	9.60	10.35	9.10	9.50	9.10	9.05	9.45	9.45
2	11.30	10.80	13.60	13.30	9.75	10.35	9.00	9.40	9.10	9.20	9.35	9.40
3	10.95	10.50	13.15	12.70	9.85	10.70	9.10	9.40	9.00	9.25	9.30	9.40
4	11.50	10.45	13.65	12.10	9.80	10.90	9.10	9.30	9.00	9.20	9.35	9.35
5	16.00	10.35	15.85	11.75	9.70	10.40	9.10	9.35	9.00	9.20	9.40	9.30
6	15.75	10.40	15.65	11.50	9.65	10.20	9.10	12.70	9.00	9.10	9.35	9.30
7	14.25	10.40	14.55	11.40	9.60	10.00	9.50	11.95	9.00	9.00	9.40	9.40
8	13.50	10.35	13.60	11.95	9 85	9.70	9.30	11.10	9.00	9.00	9.30	9.30
9	13.25	10.30	13.00	12.25	9.75	9.70	9.05	10.65	9.00	9.00	9.25	9.30
10	12.25	10.30	12.55	12.15	9.70	9.65	8.90	10.20	9.00	9.05	9.25	9.30
11	11.45	10.40	12.80	11.85	9.70	9.55	8.90	9.95	9.00	9.10	9.35	9.35
12	11.20	10.40	13.05	11.55	9.75	9.45	9.00	9.75	9.00	9.10	9.25	9.50
13	11.70	10.30	12.90	11.35	9.80	9.40	9.00	9.55	9.00	9.10	9.15	9.65
14	20.30	10.30	12.45	11.30	9.70	9.40	9.30	9.45	8.95	9.10	9.30	10.10
15	19.65	10.30	11.95	11.15	9.60	9.30	9.35	9.35	8.95	9.10	9.25	10.00
16	17.85	10.25	11.85	10.95	9.60	9.40	9.50	9.30	9.00	9.10	9.20	9.90
17	16.80	10.20	11.65	10.85	9.60	9.30	9.75	9.30	9.05	9.10	9.30	9.80
18	15.40	10.80	12.25	10.70	9.55	9.25	9.95	9.20	9.10	9.15	9.30	9.80
19	14.05	11.10	14.30	10.70	9.60	9.20	9.85	9.20	9.00	9.15	9.30	9.95
20	13.10	11.25	14.10	10.50	9.60	9.25	9.90	9.20	8.90	9.15	9.30	11.55
21	12.55	11.40	13.95	10.15	9.60	9.20	9.90	9.20	8.95	9.10	9.35	11.30
22	11.95	12.60	14.20	9.75	9.70	9.20	9.65	9.10	9.05	9.10	9.45	11.20
23	11.65	13.45	16.40	9.85	9.55	9.20	9.60	9.10	9.05	9.10	9.30	10.85
24	11.50	12.60	14.95	9.80	9.55	9.20	9.50	9.00	9.05	9.10	9.25	10.55
25	11.55	12.25	14.60	9.80	9.50	9.15	10.35	9.10	9.00	9.10	9.25	10.30
26	11.40	12.85	15.45	9.85	9.40	9.10	9.75	9.10	9.00	9.10	9.35	10.25
27	11.10	15.15	14.25	9.80	9.40	9.15	10.20	9.10	9.00	9 10	9.30	10.15
28	10.65	14.25[1]	15.05	9.75	9.40	9.10	10.05	9.10	9.05	9.25	9.30	10.10
29	10.80	.....	14.85	9.70	9.50	9.10	9.75	9.10	9.00	9.40	9.35	10.10
30	11.00	.....	14.00	9.70	9.50	9.10	9.70	9.10	9.00	9.40	9.30	9.95
31	11.05	.....	14.90	.....	9.75	.....	9.65	9.10	.....	9.40	.....	9.90

LAKE SUPERIOR OUTFLOW.

In December, 1895, and January, 1896, the United States engineers measured the outflow of Lake Superior under each of the spans of the international bridge.[1] From these and other measurements made at Spry's dock, about a mile below the rapids, the discharge at various stages of the river was computed as shown in the following table:

Discharge of St. Marys River at various stages.

Stage of river.	Discharge.
Feet.	*Second-feet.*
600.6	57,440
601.2	67,310
602.0	81,210
603.0	99,770

[1] From report by Alfred Noble, civil engineer, May 25, 1897, in Report on Compensating Works, Michigan Lake Superior Power Company, Sault Ste. Marie, Michigan, September, 1899.

It is proposed to withdraw from St. Marys River about 30,000 second-feet by a canal traversing the city of Sault Ste. Marie, Michigan, pass it through turbines installed below the Government pier and return it to the river. The turbine shafts are to be coupled directly to electric generators which are to develop 40,000 effective horsepower. The section of this canal in rock will be about 200 feet wide and carry 22 feet of flowing water. The available head has been assumed to be 19 feet, and from this a little less than 3 feet is deducted for losses by friction and other causes, leaving an effective head of a trifle over 16 feet, as given by the report of Mr. H. von Schon.

The above-described measurements were made by Mr. E. E. Haskell, assistant engineer, and briefly noted in the annual report of the Chief of Engineers, United States Army, 1896, page 4027. In the next annual report, that for 1897, on pages 4092 to 4104, are details of measurements made by Mr. E. E. Haskell during February and March, 1896. The discharge section was in the reach of river extending from the foot of St. Marys Rapids to the head of Little Rapids. It began at the foot of Spry's dock on the American side of the river and ended at Plummer's dock on the Canadian side. The total water width at this point is 2,483 feet. The river was frozen at the time of making observations, and the section was sounded and current observations made through the ice. At this time the attempt was made to measure low velocities by means of a hydrometric pendulum, but the results obtained with this instrument were not satisfactory. It was found that the friction caused by the ice was practically 31 per cent of that caused by the bottom. The discharges as measured varied from 60,470 to 77,290 second-feet.

In addition to the measurements of the outflow of Lake Superior similar work has been done on the St. Clair and Niagara rivers, results of which are to appear in the annual report of the Chief of Engineers for the year ending June 30, 1900. Investigations of Detroit and St. Lawrence rivers and additional details concerning St. Marys River are being obtained for publication a year later.

MAUMEE RIVER AT WATERVILLE, OHIO.

Maumee River is formed by the junction of St. Joseph and St. Marys rivers near Fort Wayne, Indiana, and flows in a northeasterly direction through Ohio, emptying into Lake Erie at Toledo. The southern part of the watershed is flat, the northern part being gently rolling and hilly in places. Formerly the hilly section was covered with timber, all of the best of which has been cut, leaving a section of scrub timber, with occasional farms cleared and cultivated. At the station the bed of the stream is rocky and the current sluggish, the fall being only 1.1 feet per mile on an average. Two dams have been built on the Maumee—one at Defiance, to supply water for the Ohio State

canals, and one at Grand Rapids for furnishing water power. A station was established on this river by H. A. Pressey and B. H. Flynn November 19, 1898. It is located at the highway bridge near Waterville, the gagings being made on the downstream side of the bridge. Zero of gage is on the left bank, marked by a nail in the guard rail. The wire gage is referred to a bench mark cut in the upstream side of the abutment on the left bank of the river. The elevation is 25.2 feet above gage datum. This is the lowest place on the river at which gagings can be made without being affected by backwater from the lake. The observer is J. E. Harper, station agent at Waterville, Ohio. Two measurements of discharge were made by B. H. Flynn and H. A. Pressey during 1899, as follows: The first, on March 3, at a gage height of 6.18 feet, gave a discharge of 15,490 second-feet; the second, on September 25, at a gage height of 2.15 feet, gave a discharge of 125 second-feet.

Daily gage height, in feet, of Maumee River at Waterville, Ohio, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.35	3.00	7.60	5.70	3.00	3.05	2.10	2.25	2.40	2.00	2.35	2.30
2	4.35	3.15	7.70	5.25	2.95	3.00	2.10	2.35	2.45	2.00	2.45	2.20
3	4.05	3.35	6.10	5.50	3.00	3.00	2.05	2.35	2.45	2.00	2.50	2.20
4	4.30	3.35	6.35	5.20	2.85	3.15	2.05	2.35	2.40	2.00	2.40	2.15
5	5.15	3.45	6.75	5.25	2.80	3.25	1.95	2.25	2.55	2.00	2.40	2.10
6	5.70	2.75	6.35	5.10	2.80	3.10	2.05	3.55	2.70	2.00	2.35	2.10
7	5.50	3.20	6.55	4.90	2.80	3.20	2.05	4.05	2.65	2.00	2.45	2.05
8	5.15	3.80	5.60	4.90	2.95	3.10	2.10	3.75	2.55	2.00	2.60	2.00
9	4.40	3.80	5.10	4.80	3.15	3.00	2.05	3.70	2.50	2.10	2.90	2.00
10	4.45	3.80	4.80	4.70	3.25	2.95	2.10	3.60	2.40	2.10	2.90	2.00
11	4.45	3.80	5.35	4.55	3.05	2.95	1.90	3.60	2.35	2.00	2.85	2.10
12	4.10	3.80	7.00	4.30	2.95	2.95	2.00	3.60	2.30	2.00	2.90	2.20
13	3.80	3.80	8.70	4.20	2.75	2.85	2.05	3.50	2.25	2.00	2.75	2.25
14	5.00	3.80	7.75	4.20	3.05	2.80	1.90	3.40	2.20	2.00	2.75	2.30
15	8.50	3.80	6.95	4.10	3.35	2.55	1.85	3.40	2.15	1.90	2.60	2.40
16	9.50	3.80	6.30	3.20	3.30	2.50	1.80	3.05	2.10	1.90	2.50	2.45
17	9.65	3.80	6.90	3.75	3.30	2.40	1.85	2.80	2.10	1.95	2.35	2.60
18	8.80	3.80	5.95	3.65	3.15	2.35	2.05	2.55	2.00	2.10	2.25	2.75
19	7.85	3.50	7.35	3.45	3.25	2.40	2.40	2.30	2.00	2.15	2.20	3.05
20	6.55	2.95	9.25	3.50	3.35	2.30	2.80	2.20	2.00	2.20	2.20	3.90
21	5.65	3.00	9.50	3.15	3.15	2.15	2.75	2.20	2.00	2.20	2.15	4.50
22	4.90	4.05	8.90	3.00	3.15	2.10	2.65	2.15	2.00	2.10	2.20	5.25
23	4.50	4.50	8.35	3.05	3.35	2.20	2.60	2.10	2.00	2.10	2.35	5.05
24	4.20	5.20	8.10	3.20	3.15	2.30	2.40	2.10	2.00	2.10	2.40	4.50
25	3.95	5.50	7.30	3.35	3.00	2.20	2.40	2.05	2.05	2.10	2.50	4.10
26	4.00	6.10	7.15	3.65	2.75	2.25	2.30	2.15	2.10	2.05	2.50	4.10
27	2.50	8.35	7.00	3.70	2.85	2.20	2.35	2.20	2.00	2.00	2.40	4.00
28	3.70	8.40	6.65	3.35	3.30	2.25	2.50	2.25	2.00	2.05	2.40	4.00
29	2.90	.....	6.10	3.10	3.30	2.20	2.45	2.30	2.10	2.00	2.40	4.00
30	3.00	.....	5.75	3.10	3.05	2.15	2.40	2.25	2.10	2.10	2.30	4.00
31	2.70	.....	5.65	.....	3.00	.....	2.35	2.35	.....	2.20	.....	4.00

SANDUSKY RIVER AT MEXICO, OHIO.

This river rises in the north-central part of Ohio and flows in a westerly and northerly direction into Sandusky Bay, an arm of Lake Erie. Its watershed is largely used for farming and pasturage, having only an occasional patch of forest. Sixteen dams have been built along its course in order to utilize the water power. Only five of these are now in use, but the flow is more or less obstructed by them all.

Measurements of flow were begun in November, 1898, in connection with the work of the State board of health in their study of the pollution of the Ohio streams and also to obtain information in regard to water power. Two stations have been established on the Sandusky, one at Mexico, 6 miles above Tiffin, and the other at Fremont, about 15 miles from the mouth of the river. The Mexico station was established by H. A. Pressey and B. H. Flynn on November 17, 1898, and is located at the highway bridge near Mexico, about 40 miles above Fremont, Ohio. The wire gage is on the upstream side of the bridge, and is referred to a bench mark cut in the top side of the upstream wing of the right abutment of the bridge. The elevation of the bench mark is 30.00 feet above gage datum. Gagings are made from the downstream side of the bridge, the initial point being on the left bank, marked by a nail in the guard rail. The stream flows through a long stretch of clay banks, with little sand and gravel, and is unobstructed near the point of measurement. At extreme high water the banks are overflowed, and at very low water the measurements are somewhat uncertain, owing to the sluggishness of the stream. The observer is M. L. Estep, of Mexico, Ohio. One measurement of discharge was made by B. H. Flynn in March, 1899, at a gage height of 5.40 feet, which gave a discharge of 1,386 second-feet.

Daily gage height, in feet, of Sandusky River at Mexico, Ohio, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.00	1.90	5.60	6.40	1.50	4.10	1.10	1.40	0.60	0.60	1.10	1.20
2	2.90	1.90	4.30	6.00	1.40	4.10	1.00	1.30	.50	.60	1.10	1.20
3	2.80	1.80	4.00	4.90	1.40	3.70	1.00	1.30	.60	.60	1.00	1.20
4	3.10	1.80	5.00	4.70	1.30	3.00	1.00	1.30	.50	.60	1.20	1.20
5	10.20	1.70	9.40	4.20	2.40	2.40	.90	1.20	.50	.60	1.20	1.30
6	10.80	1.70	10.80	3.40	1.90	2.00	.90	2.50	.50	.50	1.10	1.60
7	9.80	1.70	9.20	3.00	2.20	2.00	.90	2.10	.50	.50	1.10	1.40
8	6.10	1.60	6.30	4.80	2.00	2.50	.80	1.60	.60	.50	1.10	1.30
9	4.00	1.60	4.50	5.80	1.80	3.00	.80	1.40	.60	.50	1.10	1.20
10	3.50	1.60	4.00	5.00	1.60	2.40	.80	1.40	.60	.50	1.00	1.20
11	3.50	1.60	7.80	4.10	1.50	2.00	.80	1.40	.60	.50	1.00	1.20
12	3.40	1.60	8.40	3.20	1.40	1.80	.80	1.30	.60	.60	1.00	1.30
13	3.40	1.60	6.50	3.50	1.90	1.70	.70	1.30	.50	.60	1.00	1.60
14	10.20	1.60	4.80	3.40	1.50	1.50	.70	1.20	.50	.80	1.00	1.60
15	15.50	1.60	3.80	3.00	1.40	1.40	1.10	1.20	.50	.80	1.10	1.80
16	17.00	1.50	3.70	2.50	1.30	1.30	1.50	1.00	.50	.80	1.20	1.80
17	15.30	1.50	3.70	2.30	1.30	1.30	1.60	.90	.60	.80	1.20	1.70
18	10.30	1.50	3.90	2.00	2.20	1.20	1.50	.90	.60	.80	1.20	1.90
19	6.30	1.50	11.00	2.00	4.20	1.10	1.40	.90	.60	.70	1.20	2.20
20	4.20	1.50	11.80	1.90	3.20	1.00	1.30	.80	.80	.80	1.20	3.00
21	3.60	1.50	9.30	1.90	2.40	1.00	1.30	.80	.80	1.00	1.20	3.30
22	3.40	8.10	7.30	1.80	2.00	.90	1.30	.80	.70	1.00	1.10	2.80
23	3.20	9.20	9.30	1.80	1.80	.90	1.20	.80	.60	1.00	1.10	2.40
24	3.00	7.20	10.10	1.60	1.70	.80	1.20	.80	.60	1.00	1.20	2.20
25	3.00	5.00	9.50	1.80	1.60	1.30	1.20	.70	.60	1.00	1.20	2.20
26	2.90	5.40	7.40	1.80	1.60	1.20	1.20	.70	.60	1.00	1.20	2.10
27	2.70	9.20	6.40	1.80	1.50	1.20	1.10	.70	.60	1.10	1.20	2.10
28	2.60	8.40	6.00	1.80	1.50	1.20	1.20	.70	.60	1.10	1.30	2.00
29	2.40	.....	5.50	1.70	1.60	1.10	1.50	.60	.60	1.20	1.20	2.00
30	2.20	.....	6.10	1.60	3.40	1.10	1.50	.60	.60	1.20	1.20	1.80
31	2.00	.....	5.90	.....	4.70	.....	1.40	.60	.....	1.20	.....	1.60

SANDUSKY RIVER AT FREMONT, OHIO.

This station, established by H. A. Pressey and B. H. Flynn on November 18, 1898, is at the bridge of the Lake Shore Railroad at Fremont, Ohio. The gagings are made from the board walk on the lower cord of the bridge, the initial point being a cross cut on the bottom lateral at the west end of the bridge. The gage is an iron pipe graduated to feet and tenths, located at the waterworks intake, and is referred to a bench mark cut on top of south end of west abutment of bridge. The elevation of bench mark is 20.1 feet above gage datum. The bed is rocky, the banks high and not subject to overflow. During the summer of 1899, owing to the scarcity of water for the waterworks of Fremont, the rubble dam below the station was rebuilt, affecting the flow of the river and gage readings, especially at time of low water. The observer is Charles F. Reiff, superintendent of the waterworks at Fremont, Ohio. A measurement of discharge was made March 2, 1899, by B. H. Flynn: Gage height, 2.32 feet; discharge, 1,784 second-feet.

Daily gage height, in feet, of Sandusky River at Fremont, Ohio, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.00	1.30	2.95	2.90	0.40	2.20	—0.05	+0.05	0.35	0.75	0.95	0.90
2	1.75	1.20	2.25	2.75	.35	2.15	— .15	.10	.40	.70	.95	.90
3	1.70	1.20	2.05	2.45	.30	1.95	— .25	.05	.35	.75	1.05	.95
4	2.30	1.20	2.75	2.55	.40	1.55	— .25	.00	.40	.75	1.05	1.00
5	5.15	1.20	4.80	2.30	1.55	1.10	— .15	.00	.35	.75	1.05	.95
6	4.90	1.10	4.55	1 95	1.00	.85	— .15	— .10	.40	.70	1.05	.95
7	4.40	1.10	3.75	1.80	.85	.80	— .15	+ .55	.45	.60	.95	.95
8	3.25	1.05	2.95	2.75	.95	.75	— .10	.25	.45	.60	.90	.95
9	2.70	.75	2.40	2.85	.75	1.40	— .20	.10	.45	.60	.90	.95
10	2.35	.70	2.65	2.50	.65	1.30	— .10	.00	.40	.60	.90	.90
11	2.15	.80	4.40	2 10	.50	1.00	+ .05	.00	.40	.60	.90	1.00
12	2.15	.80	4.05	2.00	.45	.75	— .15	.00	.30	.45	.95	1.00
13	2.50	.80	3.15	1.95	.40	.55	— .15	— .15	.30	.50	.95	1.05
14	7.80	.80	2.10	1.75	.40	.35	— .20	— .10	.30	.70	.95	1.20
15	8.25	.80	2.10	1.50	.40	.30	— .20	— .10	.30	.70	.90	1.20
16	7.40	.75	1.95	1.25	.35	.20	+ .60	— .15	.50	.75	.90	1.20
17	6.80	.80	1.90	1.05	.40	.20	.55	— .20	.50	.85	.95	1.10
18	5.00	1.00	2.85	.90	.85	.10	.35	— .15	.50	.85	.95	1.10
19	3.40	1.05	6.70	.80	1.55	.10	.15	— .20	.65	.95	.95	1.50
20	2.90	1.55	5.05	.80	1.55	.10	.10	— .25	.60	.85	1.00	1.90
21	2.55	2.05	4.05	.70	1.00	.00	.00	— .25	.55	.85	.95	1.90
22	2.25	4.25	4.00	.65	.75	.00	.05	— .25	.55	.85	.95	1.70
23	2.20	4.00	4.65	.60	.55	.09	— .10	— .25	.55	.85	.90	1.50
24	2.20	3.30	4.20	.60	.45	— .05	— .10	— .25	.65	.85	.95	1.40
25	2.30	2.50	3.80	1.15	.35	— .05	+ .05	— .35	.80	.85	.95	1.50
26	2.15	3.40	3.60	1.00	.30	.00	— .10	— .40	.70	.85	.95	1.25
27	2.10	4.20	3.10	.75	.35	— .05	— .15	— .30	.70	.85	.95	1.10
28	1.65	3.60	2.85	.70	.55	.00	— .15	— .35	.80	.95	.95	1.10
29	1.55	.....	2.80	.60	1.20	— .05	— .15	— .25	.80	.95	.95	1.10
30	1.45	.....	2.90	.55	2.15	— .05	— .15	— .05	.70	.90	.90	1.00
31	1.35	.....	2.85	.....	2.50	.....	— .05	+ .20	.....	1.05	.....	.95

NIAGARA RIVER BELOW BUFFALO, NEW YORK.

Measurements of Niagara River were made under the direction of the United States Board of Engineers on Deep Waterways, from September, 1897, to September, 1898, the work being in charge of E. E. Haskell, assistant engineer. The results are discussed in a paper prepared by Mr. Clinton B. Stewart, assisting Mr. Haskell, and presented to the Western Society of Engineers in December,

1899.[1] The point of measurement was on the north side of the international bridge, about 3 miles below the head of the river. At this point the total width is 1,806 feet, of which 128.5 feet is taken up by the width of the eight bridge piers. The distance between soundings was about 20 feet. The soundings were made with a 41-pound cast-iron weight attached to a sash chain, in swift and deep water, and with a 25-pound lead in the shallower water. Velocity measurements were made by means of Haskell current meters with high and low pitch wheels. The velocity of the current was determined at points about 80 feet apart and at 0.3 of the total depth. Measurements of velocity near the surface were also taken, with the meter immersed 1 foot, also near the bottom, with the weight just clearing, so that the meter wheel was 1.5 feet above the bottom.

At a water-surface elevation of 567.0 feet above mean tide at New York, the area of cross section was 39,629 square feet. The discharge measurements covered a range of about 2.3 feet in lake level. Taking the elevation of mean level of Lake Erie at 572.78, this being the average at Cleveland for the period 1875 to 1898, the corresponding discharge, when corrected, is placed at 221,500 second-feet. The rate of increase in discharge at this elevation is about 25,000 second-feet per foot rise.

In the results of this investigation published by Mr. Clinton B. Stewart in the Journal of the Western Society of Engineers, the gages showing height of water at the time of measurements were located, one on the American shore and the other on the Canadian shore, each about 2½ miles from the mouth of the river. These were read during the months of July and August, 1898, simultaneously at ten-minute intervals throughout the day. They have been referred to the gage near Buffalo, readings of which were made from 1887 to 1897. The fall from these to the latter is 0.13 foot. No attempt has been made to estimate the daily flow. It is probable that this can be done, as the bed of the river is of rock and not subject to change. The construction of the international bridge about 1870 may have changed the slope conditions slightly, but probably has not influenced the flow by more than a few per cent.

The measurements of the outflow of Lake Erie through Niagara River were continued from September, 1898, by the Corps of Engineers, United States Army, in charge of the survey of northern and northwestern lakes, of which Mr. E. E. Haskell was assistant engineer and Mr. F. C. Shenehon was resident engineer. From the measurements made by these two parties the outflow, by months, for the years 1895 to 1898 has been computed and published.[2] The mean discharge for these thirty-four years is 220,428 second-feet. The following table gives the results, by months, in condensed form:

[1] Journal of Western Society of Engineers for 1899, pp. 450 to 492.

[2] Regulation of the Level of Lake Erie. Fifty-sixth Congress, first session, H. R. Doc. No. 200, pp. 15 and 16.

Mean monthly discharge of Niagara River below Buffalo, New York, for years 1865 to 1898, inclusive, in thousands of cubic feet per second.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1865.	205	193	200	216	231	230	229	227	226	219	210	206	216
1866.	200	197	205	219	225	231	234	228	226	226	220	220	219
1867.	213	206	215	223	236	244	239	231	221	213	202	197	220
1868.	192	185	197	216	227	237	236	223	216	206	202	198	211
1869.	197	196	206	214	227	237	245	242	235	223	212	221	221
1870.	227	232	227	244	249	249	250	248	241	231	224	221	237
1871.	216	208	219	231	238	238	238	232	228	212	207	198	222
1872.	196	191	189	193	203	211	211	210	205	201	194	189	199
1873.	187	187	189	217	234	236	236	234	224	217	212	221	216
1874.	231	232	238	237	240	241	242	238	226	215	205	201	228
1875.	196	192	195	204	215	225	229	228	225	213	209	214	211
1876.	214	227	244	259	268	272	268	260	255	240	242	233	248
1877.	223	219	214	224	230	232	239	235	233	223	221	223	226
1878.	225	228	232	243	250	250	250	243	240	231	226	228	237
1879.	217	214	214	223	227	229	230	225	216	211	200	206	218
1880.	218	219	222	226	233	236	238	232	226	215	214	206	224
1881.	196	199	206	223	238	239	238	230	221	220	215	220	220
1882.	232	232	244	250	256	260	258	254	247	235	226	214	242
1883.	212	217	221	224	236	255	261	259	250	242	232	232	237
1884.	224	231	236	250	258	260	254	250	238	229	217	216	239
1885.	211	206	208	223	242	256	255	255	251	248	245	243	236
1886.	244	225	220	243	251	254	253	247	241	235	224	226	239
1887.	220	230	252	253	258	259	252	243	237	222	215	216	238
1888.	211	205	207	223	229	232	236	233	222	213	215	212	220
1889.	212	209	205	213	217	228	233	225	216	206	200	206	214
1890.	214	221	224	237	246	256	245	234	229	224	223	218	231
1891.	212	212	223	220	215	219	216	210	206	197	188	189	209
1892.	190	186	187	198	217	226	239	230	222	209	201	195	209
1893.	187	189	193	210	230	235	228	220	210	202	194	195	208
1894.	202	199	200	209	218	225	223	214	210	202	197	195	208
1895.	188	184	184	189	194	196	193	192	189	180	178	181	187
1896.	183	181	180	189	198	204	201	206	198	193	186	186	192
1897.	186	190	198	210	218	220	220	216	210	198	196	195	205
1898.	196	200	206	220	224	225	219	214	205	201	198	195	209

SENECA RIVER AT BALDWINSVILLE, NEW YORK.

This stream has its source in the lake of the same name in central New York; its general course is northeasterly until its junction with the Oneida River in Onondaga County, where the two form the Oswego River, which flows northwesterly, entering Lake Ontario at the city of Oswego. The station is located at the dam on Seneca River at Baldwinsville, where the drainage area is 3,103 square miles. A head or crest gage is placed at each end of the dam and both are read twice daily. Only one tailrace gage was placed. The elevation of the zeros of the crest gages is 93.99 feet, while the elevation of the zero of the tailrace gage is 84.91 feet, or a difference of 9.08 feet. To obtain the effective heads on the water wheels it is necessary to add to the daily readings of the crest gages 9.08 feet, and subtract the readings of the tailrace gage. Ten mills utilize the flow here developed for power purposes, and to get the entire flow of the river it is necessary to keep a record of the different heads on the wheel gates as well as the amount of opening of each. The records at this point, as well as on various other streams in the State of New York, were begun by Mr. George W. Rafter for the United States Board of Engineers on Deep Waterways. The computations of discharge are quite laborious and have been made as noted in Volume XXVI of the Proceedings of the American Society of Civil Engineers, page 308. The following figures are based on Bazin's experiments. The Oswego Canal is fed from Seneca River, and practically its entire flow should be added to that

of the stream to obtain the total yield of the watershed. The discharge of this canal, including both lockage and leakage, was taken as 70 second-feet from June to October, 1899.

Estimated daily discharge, in second-feet, of Seneca River at Baldwinsville, New York, for 1898.

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1	.....	2,528	10	.....	2,389	19	3,308	2,151	28	3,119	3,449
2	.....	2,512	11	.....	1,872	20	2,590	2,292	29	2,810	3,191
3	.....	2,609	12	3,011	2,219	21	3,293	2,418	30	2,801	3,326
4	.....	2,379	13	2,625	2,078	22	3,174	2,927	31	.....	3,365
5	.....	2,889	14	3,583	2,056	23	3,234	3,455			
6	.....	2,715	15	3,684	1,982	24	3,236	3,838	Mean	3,142	2,689
7	.....	2,981	16	3,500	2,111	25	3,257	3,661			
8	.....	2,687	17	3,418	2,271	26	3,245	3,630			
9	.....	2,467	18	3,270	1,551	27	2,452	3,368			

Estimated daily discharge, in second-feet, of Seneca River at Baldwinsville, New York, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2,630	1,838	3,292	4,599	3,406	2,073	1,067	585	570	134	1,328	1,415
2	2,686	1,791	3,172	4,495	3,321	1,992	156	572	630	658	1,386	1,454
3	2,454	1,953	3,252	4,606	3,230	1,132	771	560	112	650	1,220	1,050
4	2,547	1,794	3,249	4,567	3,062	1,884	163	540	650	606	1,502	1,631
5	2,993	1,835	3,468	4,520	3,007	2,085	1,141	532	505	613	1,270	1,496
6	3,202	1,793	3,455	4,329	2,906	2,058	1,185	70	670	610	1,798	1,450
7	2,977	1,676	4,190	4,072	2,992	1,859	1,142	621	671	653	1,543	1,455
8	2,543	1,653	3,992	4,509	2,799	1,467	825	533	591	70	1,462	1,380
9	2,779	1,293	3,943	4,394	2,842	1,713	678	532	623	636	1,516	1,650
10	2,696	1,267	3,838	5,019	2,705	2,038	1,103	499	158	550	1,597	1,306
11	2,645	1,267	3,783	4,955	2,962	834	1,188	475	521	525	1,631	1,742
12	2,554	1,241	3,623	5,347	2,614	1,631	1,215	491	490	624	1,708	1,759
13	2,535	1,340	3,915	5,181	2,637	1,541	1,258	74	422	646	1,786	1,828
14	2,577	1,419	3,960	5,218	2,902	1,526	1,182	339	409	629	1,527	1,724
15	2,950	1,380	3,960	5,327	2,477	1,608	1,207	575	437	74	1,544	1,501
16	3,186	1,101	3,978	4,874	2,398	1,581	174	521	513	787	1,545	1,533
17	3,628	1,226	3,872	4,769	2,534	1,797	1,226	99	70	765	1,599	1,565
18	3,708	1,502	3,678	5,063	2,355	789	1,155	571	514	765	1,518	1,565
19	3,769	1,652	3,413	4,981	2,415	1,303	922	545	508	765	1,742	1,878
20	3,645	1,494	3,821	4,791	2,536	569	574	70	623	781	1,966	1,470
21	3,469	1,685	3,825	4,906	2,702	583	712	580	488	834	1,712	1,960
22	3,272	2,056	3,563	4,820	2,576	646	543	596	397	301	1,670	2,096
23	3,298	2,403	3,755	4,040	2,309	756	206	614	177	875	1,739	2,045
24	3,310	2,488	4,021	4,311	2,257	895	656	502	562	798	1,757	2,050
25	3,209	2,646	4,091	4,026	2,334	386	585	548	573	787	1,904	2,050
26	3,095	2,482	4,093	3,992	2,296	668	593	529	561	725	1,891	2,055
27	2,358	2,668	4,048	3,883	2,209	625	613	70	643	794	1,879	1,978
28	2,096	2,584	4,278	3,975	1,982	588	596	555	643	822	1,711	2,089
29	1,662	.....	4,776	3,853	2,045	543	531	522	691	351	1,728	2,091
30	2,028	.....	4,702	3,216	2,068	328	238	396	.....	947	1,067	2,089
31	1,871	.....	4,782	.....	2,192	.....	467	375	.....	971	.....	2,089
Mean.	2,851	1,769	3,875	4,543	2,568	1,573	776	455	481	637	1,612	1,722

CHITTENANGO CREEK AT BRIDGEPORT, NEW YORK.

This creek rises in Madison County, New York, and flows in a northerly direction between Madison and Onondaga counties into Oneida Lake, the outlet of which is Oneida River, a tributary of Oswego River. The basin of Chittenango Creek is shown on Chittenango atlas sheet of the United States Geological Survey. Observations for the computation of flow of this creek are made at the milldam in Bridgeport, New York, a short distance above its mouth. The drainage area at this point is 307 square miles. Three times a day observations are made of the river height above the crest of

the dam, head on wheels, and the amount of gate opening. Jefferson Downs, of the flour mill, is the observer. The mill runs three Camden turbines—two of which are 60-inch, and one 54-inch. The dam is of timber, backed with stone. The elevation of the zero of the crest gage is 92.84 feet, while the zero of the tailrace gage is 85.88 feet, the difference between them being 6.96 feet. In computing the flow over the dam the crest is divided into three parts, each of which is considered as a separate weir. The discharge over the dam was first computed from Bazin's experiments, but after July 1, 1899, it was computed from the results of the experiments made at Cornell University. A cross section of the dam and additional facts are given by Mr. Geo. W. Rafter in Volume XXVI of the Proceedings of the American Society of Civil Engineers, page 309.

Estimated daily discharge, in second-feet, of Chittenango Creek at Bridgeport, New York, for 1898.

Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.
1	.....	180	562	427	12	.....	196	1,571	434	23	115	465	593	1,293
2	.....	205	559	360	13	.....	197	1,295	454	24	135	487	569	1,401
3	.....	171	434	348	14	.....	181	921	442	25	85	473	490	1,075
4	.....	172	358	385	15	.....	354	790	450	26	142	352	442	857
5	.....	156	379	471	16	82	335	694	472	27	149	867	465	726
6	.....	309	385	414	17	116	299	615	619	28	214	972	523	541
7	.....	235	331	404	18	53	284	500	605	29	154	661	413	480
8	.....	204	359	320	19	119	297	506	678	30	198	565	421	630
9	.....	130	396	261	20	139	320	675	669	31	.....	519	.....	630
10	.....	165	474	265	21	117	269	728	798					
11	.....	194	1,399	465	22	111	463	623	1,155	Mean	129	344	612	597

Estimated daily discharge, in second-feet, of Chittenango Creek at Bridgeport, New York, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	515	520	632	837	447	426	116	84	81	75	60	113
2	571	484	473	795	357	346	55	79	49	90	145	127
3	636	440	385	752	310	234	97	169	45	91	145	143
4	737	465	520	861	172	105	113	126	133	90	160	159
5	1067	385	1260	866	172	184	132	134	81	80	165	149
6	1310	356	1331	864	157	229	99	70	76	141	228	151
7	1282	342	1475	857	95	229	123	125	74	89	128	166
8	1135	465	1069	1420	172	244	132	125	96	45	120	179
9	724	385	860	1675	172	192	45	134	96	107	108	155
10	486	385	852	1369	227	147	89	79	15	117	65	168
11	473	385	659	1306	237	70	282	62	71	101	46	181
12	623	385	565	1274	172	169	271	44	96	101	35	211
13	849	538	1196	1597	172	192	162	15	92	85	72	328
14	738	524	1061	1737	165	182	169	141	56	72	57	395
15	1260	462	970	1614	180	109	99	125	88	15	65	395
16	1280	362	665	1405	174	184	70	108	79	84	60	374
17	1101	449	634	1339	250	192	101	87	25	30	88	355
18	632	354	526	1221	310	70	221	76	89	38	57	466
19	390	385	565	859	374	152	210	91	74	38	25	706
20	395	541	736	861	374	84	204	25	96	45	83	588
21	389	444	766	629	385	92	152	120	117	47	70	298
22	385	619	962	447	281	100	117	109	39	15	78	304
23	399	950	1061	165	265	124	70	96	84	60	100	254
24	372	1074	1345	627	252	134	102	(a)	25	68	102	200
25	311	1314	1061	527	197	70	102	.....	67	43	110	139
26	362	1015	885	456	195	141	122	.....	49	57	25	238
27	308	645	626	331	227	109	110	.....	112	48	109	261
28	332	755	760	279	225	109	88	.....	119	25	133	201
29	385	.....	1075	359	312	84	109	56	96	20	114	249
30	448	.....	1360	295	333	91	45	96	79	65	105	244
31	637	.....	1390	.....	229	.....	141	112	.....	65	.....	240
Mean.	662	551	898	921	245	161	123	96	76	64	95	281

a Repairing dam; water drawn off August 25 to 28.

ONEIDA CREEK AT KENWOOD, NEW YORK.

This stream rises in Madison County, New York, and flows in a northwesterly direction, crossing the Erie Canal and emptying into Oneida Lake at its southeastern extremity. It is shown on the Oneida atlas sheet of the United States Geological Survey. The station is located at the silk-mill dam in Kenwood, about 3 miles from Oneida, the drainage area at this point being 59 square miles. One gage gives the height of water above the crest of the dam, and two gages are read at the silk mill, giving the head on wheels. From these readings and from the number of gate openings the quantity of water passing over the dam as well as through the wheels is determined, thus giving the discharge of the creek at this point. The dam is of timber, well constructed, and without leakage. Computations of the flow over it have been made from Bazin's experiments of 1894. The computations for the discharge measurements after July 1, 1899, are based on the coefficients determined at Cornell University. The cross section of the dam is shown in Volume XXVI of the Proceedings of the American Society of Civil Engineers, page 309.

Estimated daily discharge, in second-feet, of Oneida Creek at Kenwood, New York, for 1899.

Day.	May.	June.	July.	Oct.	Nov.	Dec.	Day.	May.	June.	July.	Oct.	Nov.	Dec.
1	71	46	18	15	144	23	18	68	30	28	25	22	130
2	60	36	20	21	69	29	19	66	26	26	24	25	97
3	60	36	20	21	56	25	20	91	31	26	24	28	79
4	59	35	20	21	66	27	21	80	26	24	25	24	82
5	54	31	30	21	55	29	22	82	26	25	.....	26	80
6	55	31	34	21	44	29	23	63	31	10	25	24	68
7	48	31	21	24	40	25	24	54	31	26	25	26	55
8	53	24	41	.....	26	33	25	66	31	21	24	24	70
9	53	24	40	24	26	41	26	43	31	21	25	25	36
10	53	24	51	24	24	125	27	43	31	20	24	26	39
11	54	25	26	21	26	97	28	71	24	21	25	26	37
12	59	26	24	24	27	70	29	108	24	18	.....	26	34
13	59	26	24	24	28	70	30	76	21	10	29	26	27
14	48	26	24	24	26	91	31	59	.....	21	31	.....	34
15	53	51	21	.....	22	82							
16	60	41	20	25	26	73	Mean.	62	30	25	24	33	60
17	61	36	31	25	26	130							

Record not kept for August and September.

WEST BRANCH OF FISH CREEK AT McCONNELLSVILLE, NEW YORK.

This stream rises in the northern part of Oneida County and flows in a southerly direction to its junction with the East Branch, where it forms the main Fish Creek, which stream flows in a westerly direction, emptying into the east end of Oneida Lake. The lower part of the course of Fish Creek is shown on the Oneida atlas sheet of the United States Geological Survey. The station is located at the Harden dam in McConnellsville. The drainage area at this point is 186.7 square miles. The dam is of timber, with a small leakage. The crest has been so repaired by the Board on Deep Waterways that it is horizontal. The record of gage heights is voluntarily kept by

Frank S. Harden, on a gage showing the height of the river above the crest of the dam and also on one at the end of the tailrace. The flow of this dam is computed from Bazin's experiments; series 170, up to July 1, 1899, and after that date they are based on the experiments made at Cornell University, as noted in Volume XXVI of the Proceedings of the American Society of Civil Engineers, page 310.

Estimated daily discharge, in second-feet, of West Branch of Fish Creek at McConnellsville, New York, for 1898.

Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.
1	.....	137	365	237	12	.....	87	997	199	23	57	700	216	317
2	.....	50	319	245	13	100	124	700	186	24	332	750	300	468
3	.....	111	282	217	14	90	134	734	212	25	360	624	329	390
4	.....	121	172	195	15	96	397	434	162	26	197	434	319	285
5	.....	130	155	182	16	47	360	514	157	27	231	1,097	255	285
6	.....	137	120	182	17	47	562	365	147	28	181	871	299	225
7	.....	131	146	196	18	50	346	365	120	29	181	686	251	170
8	.....	122	138	182	19	98	227	365	187	30	147	440	172	120
9	.....	65	135	199	20	81	190	370	157	31	.....	464	.....	120
10	.....	102	557	180	21	57	172	371	190					
11	.....	81	1,562	140	22	55	467	220	287	Mean.	134	333	384	210

Estimated daily discharge, in second-feet, of West Branch of Fish Creek at McConnellsville, New York, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	Day.	Jan.	Feb.	Mar.	Apr.	May.
1	120	228	402	586	273	18	615	133	567	1644	189
2	126	183	402	520	313	19	615	120	485	1434	374
3	194	183	438	601	243	20	530	183	505	1174	374
4	281	172	595	601	184	21	495	198	433	1085	255
5	321	120	700	601	184	22	360	258	442	1045	303
6	396	212	956	591	184	23	314	338	443	940	244
7	396	156	856	689	120	24	425	438	442	664	194
8	285	156	700	1557	183	25	350	438	442	564	189
9	352	147	656	2110	154	26	325	360	360	470	174
10	422	136	583	1690	154	27	338	408	552	366	134
11	502	117	546	1724	183	28	308	408	599	366	50
12	587	80	700	2055	243	29	225	.....	599	364	700
13	873	99	1178	2440	194	30	278	.....	599	220	455
14	873	132	1178	2920	120	31	278	.....	599	.....	483
15	795	94	1178	3040	189						
16	787	131	972	2410	189	Mean.	435	206	615	1,206	239
17	735	148	782	1720	189						

EAST BRANCH OF FISH CREEK ABOVE POINT ROCK, NEW YORK.

This stream rises in Lewis County, New York, and flows in a southerly direction into Oneida County, where it joins the West Branch to form the main Fish Creek. The station is located at the sawmill of Fowler W. Willson at Point Rock. The dam is of timber and has considerable leakage. The old sawmill located here is seldom used; whenever the wheels are running, however, record is kept of the length of time and of the amount of gate openings. The profile of crest of dam is somewhat irregular and, in order to facilitate computations, has been divided into five sections, the flow through each of which has been computed separately by Bazin's experiments of 1894. The discharge measurements after July 1, 1899, are based on experiments made at

Cornell University, as noted in Volume XXVI of the Proceedings of the American Society of Civil Engineers, page 310.

Estimated daily discharge, in second-feet, of East Branch of Fish Creek at Point Rock, New York, for 1898.

Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.
1	.....	160	340	325	12	.....	225	320	360	23	155	1,090	370	660
2	.....	100	320	325	13	.....	250	485	340	24	690	710	370	745
3	.....	100	250	360	14	.....	295	450	385	25	420	460	345	880
4	.....	80	245	340	15	.....	600	395	335	26	300	450	325	850
5	.....	210	210	340	16	.....	555	370	510	27	265	1,245	325	805
6	.....	295	385	340	17	.....	350	310	520	28	370	710	340	630
7	.....	240	415	345	18	.....	250	340	520	29	300	490	385	490
8	.....	210	350	360	19	.....	230	345	570	30	160	400	370	610
9	.....	185	400	370	20	.....	310	340	600	31	.....	370	.....	810
10	.....	185	720	350	21	.....	240	310	630					
11	.....	170	1830	360	22	10	860	265	685	Mean.	296	387	424	501

Estimated daily discharge, in second-feet, of East Branch of Fish Creek at Point Rock, New York, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	565	475	748	970	2,745	305	(a)	(a)	(a)	25	650	1,200
2	670	475	810	1,040	2,280	390	.....	.....	.....	21	650	1,230
3	670	420	810	1,090	1,950	270	.....	.....	.....	27	665	1,180
4	805	450	815	1,150	1,340	285	.....	.....	.....	35	660	1,160
5	1,190	420	840	1,420	930	295	.....	.....	.....	40	635	1,120
6	1,280	450	900	1,435	750	295	.....	.....	.....	60	680	1,120
7	1,280	390	1,010	1,330	660	260	.....	.....	.....	68	700	1,040
8	1,090	370	1,010	1,220	635	230	.....	.....	.....	80	710	1,000
9	1,060	420	770	1,150	540	200	.....	.....	.....	100	750	1,040
10	985	390	945	1,240	520	160	.....	.....	.....	110	790	1,000
11	930	370	1,150	1,390	510	150	.....	.....	.....	110	825	1,040
12	900	320	1,245	1,500	520	165	.....	.....	.....	120	840	1,180
13	1,005	440	1,200	1,600	570	150	.....	.....	.....	115	825	1,180
14	1,000	420	1,110	1,660	520	140	.....	.....	.....	120	840	1,040
15	770	500	1,045	1,760	580	130	.....	.....	.....	150	880	1,000
16	680	610	985	1,870	510	115	.....	.....	.....	130	860	990
17	610	640	985	1,900	500	115	.....	.....	.....	180	860	985
18	485	740	1,090	1,900	600	125	.....	.....	.....	190	880	990
19	550	760	1,150	2,030	650	150	.....	.....	.....	190	900	1,000
20	510	810	1,100	2,510	700	170	.....	.....	.....	190	900	990
21	490	750	1,060	3,170	635	175	.....	.....	.....	195	840	965
22	485	780	1,045	3,550	540	175	.....	.....	.....	220	840	915
23	425	820	1,165	4,030	410	170	.....	.....	.....	270	860	915
24	385	825	1,165	4,320	415	150	.....	.....	.....	270	900	880
25	370	900	1,235	4,650	500	120	.....	.....	.....	285	920	810
26	350	945	1,235	4,170	450	105	.....	.....	.....	290	900	960
27	320	1,050	1,165	3,490	410	95	.....	.....	.....	335	940	960
28	370	1,210	1,150	3,110	440	100	.....	.....	.....	415	1,025	1,040
29	320	.....	1,130	2,790	475	80	.....	.....	.....	510	1,080	1,045
30	320	.....	1,200	2,790	450	70	.....	.....	.....	530	1,100	1,080
31	340	.....	1,245	.....	400	.....	.....	.....	.....	620	.....	1,080
Mean.	684	612	1,049	2,208	745	177	.....	.....	.....	194	830	1,035

a Flow during July, August, and September not computed, owing to fact that all water leaked through the dam.

OSWEGO RIVER AT FULTON, NEW YORK.

This stream is formed by the junction of Oneida and Seneca rivers in Onondaga County, New York, and flows northwesterly, emptying into Lake Ontario at the city of Oswego. The station is located at the dam at Fulton, 7 miles above Oswego, the catchment area being 4,916 square miles. The dam is well built of stone and brick and has no leakage. At this point four gages are read—one above the dam,

one in the tailrace of the Fulton Worsted Mill, one in the headrace and one in the tailrace of the Oswego Falls Pulp and Paper Company's mill. The mills are located at each end of the dam, and both use water from the Oswego River. The dam is 404.6 feet in length, and the crest is practically level. During the low-water stages flashboards are placed on the crest of the dam, and in order to compute the discharge of the river at this point it is necessary to take these flashboards into account, as well as the height of the dam, the head on the various wheels, and the number of openings of the same. The records at this point are not at present available. A cross section of the dam is given in Volume XXVI of the Proceedings of the American Society of Civil Engineers, page 309.

OSWEGO RIVER AT OSWEGO, NEW YORK.

Another series of records on this stream besides the one at Fulton have been maintained at the high dam between Oswego and Fulton. The water at this point is used in the State canal and by the Oswego Waterworks Company, whose pump house is on the left side of the stream. This station was established April 1, 1897. The following figures of daily gage height were obtained from Mr. Thomas H. Bennett, superintendent of the Oswego Waterworks Company:

Daily gage height, in feet, of Oswego River at Oswego, New York, for 1897.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.38	.....	5.63	6.56	8.08	8.79	8.33	8.50	7.42
2	3.54	4.58	5.60	6.33	8.08	.....	8.38	8.29	7.42
3	3.71	4.65	5.60	6.42	.....	8.79	.....	8.17	7.33
4	.....	4.73	5.60	.....	8.08	8.83	8.67	8.17	7.44
5	3.71	4.75	.....	6.42	8.17	.....	8.46	8.25	.....
6	3.71	4.83	5.63	6.46	.....	8.92	8.42	8.17	7.08
7	3.71	4.88	5.63	6.58	8.25	8.79	8.42	.....	7.17
8	3.75	.....	5.67	6.79	.....	8.83	8.54	8 21	7.17
9	3.52	4.94	5.67	6.75	8.58	8.75	8.58	8.17	6.88
10	.....	5.00	5.67	6.79	8.50	8.83	.....	8.08	6.83
11	3.54	5.00	5.67	.....	8.50	8.83	8.46	8.17	6.75
12	3.54	.....	.....	6.50	8.42	.....	8.46	8.17	.....
13	3.54	5.04	5.67	6.83	8.50	8.42	8.54	8.25	6.79
14	3.71	5.08	5.75	6.96	8.44	8.29	8.33	8.25	6.83
15	3.71	.....	5.75	6.83	.....	8.38	8.42	.....	6.50
16	3.75	5.04	5.77	6.75	8.58	8.33	8.38	8.04	6.54
17	.....	5.04	5.85	6.75	8.42	8.50	.....	7.98	6.50
18	3.90	5.04	5.90	.....	8.42	8.54	8.79	7.92	6.50
19	4.00	5.17	.....	6.67	8.50	.....	8.42	7.83	.....
20	4.08	5.25	5.96	6.71	8.50	8.67	8.25	7.83	6.50
21	4.13	5.25	6.17	6.67	8.54	8.63	.....	.....	6.63
22	4.17	.....	6.17	6.75	.....	8.58	8.33	7.79	6.75
23	4.21	5.29	6.25	6.71	8.67	8.58	8.33	7.92	6.75
24	4.27	5.38	6.25	6.83	8.71	8.58	.....	7.79	7.17
25	4.48	5.29	6.33	.....	8.71	8.42	8.38	7.79	7.33
26	4.48	5.38	.....	6.42	8.75	.....	8.42	7.79	.....
27	4.48	5.42	6.25	6.33	8.75	8.50	8.46	7.46	7.08
28	4.48	5.42	6.38	6.33	8.75	8.21	8.42	.....	7.25
29	4.50	.....	6.21	a8.00	.....	8.54	8.50	7.17	7.46
30	4.67	5.46	6.31	8.13	8.79	8.46	8.50	7.17	7.17
31	.....	5.46	.....	8.10	8.58	.....	.....	.....	7.25

a 2.01 feet were added to the wall of the dam.

Daily gage height, in feet, of Oswego River at Oswego, New York, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	7.58	6.50	5.88	6.13	.....	7.00	8.29	8.33	7.83	.....	7.00	6.75
2	.....	6.50	5.92	6.17	6.46	.....	8.29	8.33	7.83	7.83	7.00	6.75
3	7.42	6.50	6.00	.....	6.50	6.96	.....	8.33	7.88	.....	7.00	.....
4	7.58	6.67	6.08	6.31	6.29	7.25	.....	8.00	8.17	7.83	7.00	6.96
5	7.29	6.67	6.17	6.35	6.27	7.25	.....	8.17	7.92	7.88	.....	6.75
6	7.46	.....	.....	6.44	6.25	7.25	.....	8.25	7.96	.....	7.08	6.92
7	7.25	6.50	6.29	6.50	6.21	7.25	7.83	8.25	7.96	7.92	7.02	6.75
8	7.33	6.67	6.25	6.58	.....	7.50	.....	8.08	7.67	.....	7.08	6.96
9	.....	6.63	6.25	6.67	6.21	7.50	.....	8.25	7.71	7.88	7.00	7.04
10	7.50	6.63	6.25	.....	6.25	7.58	8.00	8.25	7.67	7.96	6.42	.....
11	7.50	6.63	6.21	6.71	6.33	7.58	8.00	8.33	7.83	8.00	6.38	7.00
12	7.33	6.17	6.13	6.83	.....	7.58	7.92	8.42	7.75	8.00	.....	7.00
13	6.75	.....	.....	6.92	6.42	7.67	7.58	8.50	7.67	8.25	6.08	7.42
14	6.63	6.54	5.92	6.92	6.42	7.75	7.58	8.21	7.83	.....	6.08	7.50
15	6.50	6.63	5.88	7.00	6.46	7.77	.....	8.42	7.92	.....	6.17	7.33
16	.....	6.83	5.88	7.00	.....	.....	.....	8.25	7.92	7.67	6.25	7.25
17	6.25	6.58	5.83	.....	.....	7.90	.....	8.25	7.67	7.75	6.25	.....
18	6.54	6.00	5.88	7.10	6.71	7.90	.....	8.25	8.00	7.67	6.33	7.17
19	6.54	6.00	5.88	7.17	6.71	8.00	.....	8.25	8.00	7.67	.....	7.25
20	6.54	.....	.....	6.92	.....	8.00	.....	8.25	8.00	7.58	6.33	7.17
21	6.29	5.92	5.88	7.13	.....	8.00	.....	8.33	8.00	7.58	6.33	6.75
22	6.21	5.92	5.83	7.17	.....	8.08	.....	8.21	8.00	.....	6.25	6.50
23	.....	5.79	5.83	7.17	6.83	8.08	.....	8.25	8.00	7.33	6.38	6.13
24	5.75	5.67	5.88	.....	.....	8.13	.....	8.33	7.92	7.17	6.42	.....
25	5.75	5.67	5.88	6.50	.....	.....	.....	8.27	7.88	7.17	6.42	6.08
26	5.88	5.67	5.92	6.38	6.92	.....	.....	7.83	8.08	7.13	.....	6.08
27	5.83	.....	.....	6.25	.....	.....	.....	7.92	7.92	7.08	6.50	6.13
28	6.17	5.75	6.00	6.17	.....	8.21	.....	7.92	8.00	6.96	6.50	6.42
29	6.17	.....	6.00	6.27	.....	8.27	.....	7.92	7.92	7.00	6.58	6.25
30	.....	.....	6.04	6.29	.....	8.29	.....	7.75	7.88	.....	6.58	6.25
31	6.83	.....	6.04	.....	6.96	.....	.....	7.75	.....	7.00	.....	.....

Daily gage height, in feet, of Oswego River at Oswego, New York, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	6.54	7.21	6.83	5.92	6.08	7.33	.....	8.42	8.29	8.50	7.92
2	6.71	7.29	6.75	.....	6.08	7.33	8.00	8.33	.....	8.33	7.92
3	6.54	7.21	6.67	5.83	6.08	.....	.....	8.33	9.00	8.33	7.75
4	6.29	.....	6.67	5.83	.....	7.67	8.00	8.33	8.42	8.42	.....
5	.....	7.38	6.33	5.83	6.33	7.67	8.00	.....	8.50	8.42	7.75
6	6.25	7.38	8.25	5.83	.....	7.83	8.17	8.33	8.58	8.42	7.67
7	6.46	7.42	6.25	5.92	6.83	7.83	8.33	8.33	8.33	.....	7.75
8	6.67	8.08	6.42	.....	6.50	8.00	.....	8.50	8.50	.....	.....
9	7.00	8.67	6.50	5.25	6.67	8.17	8.00	8.33	.....	8.50	.....
10	7.08	8.50	6.50	5.33	6.83	.....	8.08	8.42	7.08	8.50	.....
11	7.00	.....	.....	5.25	6.83	8.08	8.00	8.33	8.58	8.50	.....
12	7.00	7.75	6.33	5.17	.....	8.08	8.17	.....	9.00	8.50	.....
13	6.75	7.75	6.33	5.17	.....	8.25	8.17	8.42	8.55	8.67	.....
14	.....	7.58	6.42	5.21	7.08	7.50	8.33	8.50	8.33	8.58	.....
15	6.17	7.38	6.38	.....	7.08	7.50	.....	8.42	8.75	.....	.....
16	6.13	7.25	6.33	5.25	7.00	7.50	8.08	8.33	10.58	8.58	.....
17	6.13	7.33	6.38	5.25	7.00	.....	8.25	8.33	.....	8.67	.....
18	6.25	.....	.....	5.25	7.00	7.50	8.33	9.08	.....	8.42	.....
19	6.29	7.33	6.50	5.33	7.08	7.58	8.33	.....	8.67	8.75	.....
20	6.25	7.21	6.50	5.25	.....	7.58	8.33	9.50	8.50	8.50	.....
21	.....	7.17	6.46	5.50	7.08	7.67	8.42	8.50	9.17	.....	.....
22	6.42	7.00	.....	.....	7.08	7.67	.....	8.33	8.67	8.33	.....
23	6.42	7.00	6.33	5.54	7.08	7.83	8.33	8.42	.....	8.33	.....
24	6.50	7.00	6.38	5.63	7.08	.....	8.33	8.50	9.33	8.33	.....
25	6.33	.....	.....	5.75	7.25	7.67	8.42	8.42	8.50	8.42	.....
26	6.29	6.75	6.13	5.75	7.33	7.50	.....	8.42	8.50	8.50	.....
27	7.42	6.79	6.13	5.79	.....	7.67	8.33	8.50	8.50	8.33	.....
28	7.08	6.79	6.17	5.75	7.33	.....	8.42	8.50	8.50	.....	.....
29	7.42	.....	5.83	.....	7.33	8.17	.....	8.00	8.50	8.08	.....
30	7.25	.....	5.75	6.00	7.33	8.25	8.42	8.17	.....	8.33	.....
31	7.25	.....	5.75	.....	7.33	.....	8.42	8.33	.....	8.33	.....

SALMON RIVER AT ORWELL, NEW YORK.

This river rises in Lewis County, New York, and flows in a westerly direction into Lake Ontario, a portion of its course being shown on the Pulaski atlas sheet of the United States Geological Survey. At a point about a mile below Orwell are Salmon Falls, where the river has a vertical descent of about 110 feet, but at present no attempt

has been made to utilize it. Observations were made at Orwell, at which locality the river has a drainage area of 190.5 square miles. The gages are at an old wooden dam built to furnish power for a sawmill. The dam is considerably out of repair and leaks badly. When the station was first established current-meter measurements were made of this leakage, and it was found to be 88 cubic feet per second. The profile of the crest is irregular, and in order to facilitate computation is divided into four parts, each section being computed separately and the sum total taken as the entire flow. The station was abandoned May 31, 1899, on account of the leakage through the dam, which it was difficult to estimate accurately. The results are not at present available for publication.

BLACK RIVER AT WATERTOWN, NEW YORK.

This river rises in Herkimer County and flows in a northeasterly direction into Black River Bay, an arm of Lake Ontario. A portion of its course is shown on the Watertown atlas sheet of the United States Geological Survey. Observations of the height of water have been made at the dam of the city waterworks of Watertown, located 2 miles above, at Huntingtonville. The station was established on February 22, 1897. The record in the following table has been furnished by Frank A. Hinds, civil engineer. It is the average of two daily readings.

The readings from August 22 to September 16, 1897, do not give reliable data, as the high dam on the opposite channel of the river developed a leak, which gradually increased until it became necessary to open the traps in the dam, letting the water down so that it could be repaired. It is possible that this leak commenced earlier than August 22. The conditions at this point are peculiar, in that the stream flows in two channels with an island between. There is a dam on each channel, the high dam, previously referred to, creating a settling basin for the water supply of the city of Watertown. The other dam, known as the Huntingtonville, on the opposite side of the island, is the one near which the readings given herewith are taken.

In addition to the amount of water which is indicated by the flow over this (the Huntingtonville) dam, there should be added the quantity taken from the other channel above the high dam to supply water for the city of Watertown. There is also constant leakage from seams in the rock underneath the Huntingtonville dam, where the observations are made. This quantity has been variously estimated, but direct measurements have not been made. In the following table the original readings have been diminished by dropping the figure 100; for example, the reading on February 22, 1897, of 103.10 is given below as 3.10. In a few instances this has introduced a minus quantity when the surface dropped below 100, as was the case on October 3, and 8 to 11, 1897.

The crest of the dam is irregular in profile, and for ease of computation is divided into six parts, each of these being considered horizontal.

The discharge of the river was computed by Mr. Robert E. Horton. The results, however, have been revised several times upon the acquisition of new information. Another record of Black River has been kept by the Taggart Company at Felts Mills, about 10 miles above Watertown, covering a somewhat longer period of time than that at Huntingtonville, but the figures are not at present available.

Daily gage height, in feet, of Black River at Huntingtonville dam, for 1897.

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	3.00	4.20	5.01	3.73	2.89	3.20	1.28	0.35	2.68	4.63
2	.....	.....	4.23	4.83	3.58	2.88	3.16	.95	.37	2.84	4.40
3	.....	.....	4.40	4.56	3.40	2.93	3.15	1.26	.02	3.21	3.57
4	.....	.....	4.48	4.41	3.57	2.85	3.08	1.44	.10	3.50	3.45
5	.....	3.38	4.90	4.58	3.72	2.79	2.85	1.14	.18	3.42	3.75
6	.....	3.56	5.08	4.49	3.65	2.71	2.79	1.55	.10	3.25	4.10
7	.....	3.69	5.22	4.43	3.49	2.93	2.70	1.65	.03	3.20	4.26
8	.....	3.74	5.48	4.12	3.40	2.75	2.49	1.55	.02	3.34	4.31
9	.....	3.80	5.60	3.83	3.30	2.73	2.64	1.49	.44	3.35	4.38
10	.....	3.98	5.60	3.59	4.05	2.77	2.70	1.47	.63	3.56	4.40
11	.....	4.35	5.40	3.59	4.48	2.64	3.60	1.23	.10	4.02	4.77
12	.....	4.43	5.05	3.45	4.64	2.67	4.63	.78	.35	4.03	4.53
13	.....	4.58	4.75	3.47	4.43	2.82	4.74	.71	1.68	4.15	4.70
14	.....	4.50	4.64	3.63	4.08	2.69	4.40	.80	2.92	3.92	4.60
15	.....	4.35	4.70	4.08	3.73	2.95	3.75	.35	3.00	3.82	4.73
16	.....	4.20	4.88	4.23	3.55	2.99	3.42	.00	3.45	3.63	4.91
17	.....	4.00	5.07	4.10	3.44	2.95	3.20	1.25	2.83	3.95	5.00
18	.....	3.90	5.15	3.95	3.31	2.90	3.30	1.40	2.98	4.23	4.98
19	.....	3.88	5.24	3.72	3.18	2.87	3.44	1.08	2.95	4.24	4.46
20	.....	4.38	5.18	3.64	3.10	2.89	3.28	1.28	2.88	3.90	3 75
21	.....	5.20	5.24	3.46	3.33	2.90	3.08	1.18	2.83	3.60	3.68
22	3.10	5.10	5.16	3.51	3.53	2.85	2.91	1.33	2.80	3.73	3.68
23	3.10	5.48	4.95	3.65	3.39	2.76	2.89	1.38	2.79	3.57	3.66
24	3.50	6.48	4.82	3.44	3.23	2.70	2.74	1.25	2.80	3.35	3.50
25	3.25	6.10	5.13	3.47	3.07	2.60	2.63	1.25	2.88	3.25	3.43
26	3.75	5.70	5.53	3.90	2.99	2.90	2.66	1.30	2.77	3.74	3.47
27	.....	5.45	5.80	4.13	2.89	2.87	2.67	1.30	2.79	4.90	3.39
28	.....	4.88	6.07	4.08	2.99	2.85	2.44	1.65	2.83	5.13	3.36
29	.....	4.48	6.01	3.92	2.89	3.00	2.34	1.58	2.75	5.28	3.32
30	.....	4.30	5.41	3.85	2.87	3.28	1.97	.33	2.75	4.92	3.30
31	.....	4.30	.....	3.80	.....	3.30	.68	.....	2.73	.....	3.23

Daily gage height, in feet, of Black River at Huntingtonville dam, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.21	3.55	3.40	4.75	4.03	3.55	3.09	2.95	3.01	3.14	3.65	3.48
2	3.39	3.60	3.50	4.59	3.73	3.42	3.04	3.15	3.00	2.91	3.53	3.45
3	3.28	3.57	3.40	4.20	3.78	3.31	2.84	2.96	2.95	2.94	3.50	3.45
4	3.30	3.50	3.40	3.90	3.83	3.23	2.80	3.03	2.45	2.95	3.43	3.38
5	3.34	3.55	3.35	3.80	3.89	3.21	2.95	3.10	3.05	3.08	3.40	3.40
6	3.30	3.45	3.35	3.80	4.13	3.14	2.94	3.26	3.22	3.55	3.37	3.38
7	3.25	3.50	3.35	3.75	4.06	3.13	2.98	3.20	3.19	3.70	3.65	3.28
8	3.15	3.50	3.37	3.73	3.75	3.05	2.91	3.15	3.20	3.58	3.60	3.23
9	3.25	3.45	3.52	3.65	3.55	2.98	2.88	3.01	3.28	3.27	3.60	3.18
10	3.23	3.40	3.75	3.63	3.60	3.01	2.76	2.96	3.23	3.28	3.60	3.19
11	3.23	3.68	4.53	3.63	3.45	3.11	2.82	2.95	3.10	3.19	4.98	3.13
12	3.22	4.65	5.75	3.56	3.23	3.03	2.90	2.98	3.11	3.06	5.15	3.23
13	3.63	4.93	6.75	3.51	3.80	3.05	2.90	3.05	3.03	3.03	5.13	3.23
14	4.00	4.75	7.50	3.53	3.86	3.23	2.80	3.02	2.88	3.16	5.05	3.25
15	4.10	4.55	8.10	3.60	3.72	3.35	2.90	2.70	2.90	3.53	4.78	3.25
16	4.04	4.30	7.55	3.59	3.51	3.31	2.90	3.01	2.85	3.77	4.48	3.26
17	3.99	4.05	6.70	3.48	3.50	3.23	2.88	2.90	2.84	4.03	4.08	3.30
18	3.88	3.90	6.20	3.38	3.42	3.13	2.90	2.85	2.62	3.85	3.88	3.25
19	3.78	3.80	6.00	3.48	3.35	2.97	3.09	2.88	2.80	3.62	3.70	3.28
20	3.75	3.73	5.74	3.58	3.48	3.25	2.97	2.87	2.81	3.53	3.61	3.33
21	4.00	3.85	5.83	3.85	3.58	3.35	3.00	2.88	2.96	3.52	3.71	3.33
22	4.35	3.91	5.97	3.99	3.53	3.30	3.00	2.81	2.92	3.61	3.71	3.48
23	4.35	3.89	5.87	4.25	3.44	3.23	3.00	2.95	2.85	4.02	3.63	3.98
24	4.48	3.80	5.55	4.53	3.48	3.18	2.87	3.35	3.10	4.31	3.71	4.34
25	4.43	3.69	5.18	4.73	3.55	3.05	3.08	3.50	3.54	4.08	3.56	4.30
26	4.32	3.60	4.95	5.09	3.58	3.00	3.30	3.65	3.58	3.93	3.48	4.22
27	4.12	3.55	4.65	5.33	3.85	2.93	3.20	3.66	3.55	4.33	3.18	4.00
28	3.90	3.65	4.48	5.24	3.93	3.05	3.05	3.53	3.43	4.60	3.31	3.75
29	3.74	.....	4.51	4.85	3.73	3.04	3.06	3.30	3.39	4.57	3.41	3.65
30	3.59	.....	4.75	4.40	3.69	3.08	3.08	3.10	3.25	4.25	3.50	3.83
31	3.60	.....	4.88	.....	3.66	.....	3.12	3.08	.....	3.90	.....	4.14

Daily gage height, in feet, of Black River at Huntingtonville dam, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.98	3.28	3.79	3.95	6.71	3.65	3.10	2.88	2.89	2.88	3.38	2.98
2	3.91	3.33	3.70	3.89	6.43	3.43	2.91	2.90	3.01	2.88	3.75	2.99
3	3.74	3.31	3.69	3.86	6.20	3.38	2.90	2.95	2.70	3.10	3.93	3.08
4	3.80	3.30	3.72	3.79	5.99	3.23	2.88	2.90	2.95	3.05	3.69	3.33
5	5.38	3.30	3.88	3.80	5.70	3.18	3.07	2.83	2.60	2.98	3.59	3.32
6	5.25	3.30	4.23	3.91	5.20	3.20	3.09	2.73	2.90	2.91	3.53	3.18
7	5.05	3.30	4.43	4.06	4.79	3.18	3.15	2.80	2.85	2.91	3.43	3.10
8	5.05	3.30	4.32	4.65	4.21	3.13	3.10	2.85	2.91	2.73	3.25	3.00
9	4.89	3.30	4.21	4.92	3.95	3.05	2.98	2.90	2.93	2.92	3.24	2.90
10	4.63	3.29	4.08	4.96	3.83	3.13	3.26	2.83	2.91	2.83	3.10	2.95
11	4.30	3.25	3.95	5.09	3.73	3.00	3.50	2.76	3.00	2.88	3.08	3.18
12	4.05	3.29	4.24	5.43	3.83	3.13	3.35	2.73	2.73	2.80	2.93	4.15
13	3.93	3.38	4.98	5.51	3.88	3.05	3.21	2.75	3.05	2.81	3.09	4.98
14	3.90	3.38	4.90	5.71	3.70	3.05	3.13	2.76	2.70	2.81	2.96	4.98
15	4.11	3.38	4.84	5.99	3.60	2.96	3.08	2.92	2.74	2.81	3.00	4.88
16	4.39	3.35	4.65	6.01	3.63	3.10	2.91	2.95	2.98	2.74	3.06	4.35
17	4.41	3.37	4.60	6.06	3.65	3.10	2.87	2.93	2.78	2.90	3.10	3.53
18	4.30	3.29	4.40	6.06	3.88	3.10	2.90	3.16	3.00	2.89	3.10	3.71
19	4.25	3.25	4.25	6.17	3.68	3.18	3.08	2.90	2.98	2.92	2.93	4.11
20	3.65	3.30	4.09	6.61	3.85	3.05	2.88	2.75	2.75	2.94	2.95	4.30
21	3.84	3.33	4.10	7.13	4.05	3.00	2.88	2.63	2.80	2.83	3.01	4.55
22	3.73	3.42	4.09	7.64	4.01	3.00	2.90	2.90	2.98	2.63	2.98	4.60
23	3.68	3.61	4.10	7.71	3.85	3.00	2.89	2.85	2.75	2.90	2.93	4.20
24	3.60	3.76	4.20	7.72	3.77	3.05	3.00	2.83	2.70	2.88	2.99	4.10
25	3.55	3.75	4.17	7.70	3.59	3.02	3.05	3.01	2.99	2.93	2.95	4.00
26	3.59	3.65	4.13	7.72	3.44	3.03	2.96	2.95	2.95	2.95	2.79	3.60
27	3.50	3.75	4.08	7.62	3.46	3.13	2.92	2.83	2.99	2.95	2.94	3.48
28	3.43	3.78	3.98	7.51	3.43	3.05	2.94	2.84	2.99	2.95	2.96	3.40
29	3.30	4.10	3.94	7.34	3.42	2.98	2.82	2.85	2.99	2.93	2.93	3.38
30	3.40	4.10	4.08	7.06	3.73	3.05	2.65	2.90	3.03	2.86	2.86	3.38
31	3.34	.....	3.97	.....	3.75	.....	2.68	2.88	.....	3.28	.....	3.23

ST. LAWRENCE RIVER NEAR MONTREAL, CANADA.

St. Lawrence River receives the outflow of the Great Lakes, and, discharging northeasterly, is joined by Ottawa River near the city of Montreal. About 50 miles below Montreal the river widens into what is known as Lake St. Peter. At the upper end of this lake is the town of Sorel, at which is one of the important gages for recording the height of the stream. The discharge of the river has been measured at a point about 40 miles below Montreal and a mile below the wharf at the town of Lanoraie, this place being chosen because of the excellent form of the channel. The width of the river here is between 3,000 and 3,300 feet, and the depth at low stages about 40 feet. The first measurement was made by Mr. W. J. Sproule, under the direction of the Montreal Flood Commission, by means of rod floats, on November 9 and 13, 1886. At that time the height of water was 11 feet 9 inches on the flats of Lake St. Peter. The area of cross section was 115,298 square feet, and the discharge 311,101 second-feet.[1] The next measurements were made by Prof. C. H. McLeod, of McGill University, Montreal, on November 13 and 14, 1895. At that time the water was 8 feet 9 inches in depth on the flats of Lake St. Peter, the area was 105,432 square feet, and the discharge 215,621 second-feet. The lowest water of that year (1895) occurred in the latter part of October and early in November, the water level being at the time of measurement 7 inches above the lowest

[1] Discharge of the St. Lawrence River, by Prof. C. H. McLeod: Trans. Can. Soc. Civil Engineers, Vol. X, Part I, 1896, p. 129.

point previously recorded. It is estimated that at the lowest stage of that year, which is the lowest on record, the cross section was reduced about 2 per cent, and the discharge was estimated to have been 196,000 second-feet.

On October 23 and 24, 1896, another measurement was made by Professor McLeod, giving an area of cross section of 117,500 square feet and a discharge of 258,500 second-feet. At this date the depth of water on the flats of Lake St. Peter was 10 feet and 7 inches. All depths on these flats have been obtained by reduction from the zero readings taken on the gage at Sorel, the zero of which is said to correspond to 9 feet 6 inches below the level of the flats, and to +0.05 on Steikel's datum, as noted in the Reports of the Public Works Department, Canada, for 1890–91. The height of water at this section is known to be influenced slightly by the tides, but the effect on the discharge has not been investigated.

The discharge of Ottawa River was measured on September 27 and 28, 1899, at a point about 2 miles below the dam at Carillon. The cross section measured 50,000 square feet and the discharge 39,600 second-feet. At the time of the measurement the reading of the gage at Lock No. 1 of Carillon Canal gave 12.0 feet on the lower sill.

MISSISSIPPI RIVER AT ST. PAUL, MINNESOTA.

Measurements of discharge of the Mississippi River at St. Paul, below the mouth of the Minnesota River, have been made for a number of years by the Engineer Corps of the United States Army. The object of the measurements is the determination of the effect of the reservoirs at the head of the Mississippi River in maintaining deep or navigable water during the periods of drought. Measurements and computations of the amount of water discharged from reservoirs at such seasons are made and comparisons had with the behavior of the river at St. Paul and lower places. Observations of river height are made at the United States Weather Bureau gage located on a wharf near the foot of Jackson street. The zero of this gage is at an elevation of 683.334 feet. The measurements are made from a boat, at a section about halfway between Wabash street bridge and Roberts street bridge, in the city of St. Paul. Every time a series of observations are made two wires are stretched across the river parallel to each other and at a distance of 13 feet apart. Upon the completion of the measurement the wires are reeled up separately on apparatus especially constructed for the purpose, as it is impossible to maintain permanent cables across the river, on account of obstructing navigation. The bridges in the city are too high for satisfactory work. Records of height are maintained by the United States Weather Bureau and are furnished to this office. Results of measurements may be found as follows: 1897, Nineteenth Annual Report, Part IV, page 267; 1898, Twentieth Annual Report, Part IV, page 230.

Daily gage height, in feet, of Mississippi River at St. Paul, Minnesota, for 1899.[1]

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	Frozen.	Frozen.	Frozen.	Frozen.	6.4	5.7	8.7	4.0	7.5	4.4	7.2	4.7
2	....do..	....do..	....do..	....do..	6.6	6.6	8.7	3.8	7.2	4.3	7.1	4.7
3	....do..	....do..	....do..	....do..	6.8	7.7	8.5	3.7	6.9	4.2	7.0	4.6
4	....do..	....do..	....do..	....do..	7.0	8.2	8.3	3.7	6.7	4.2	6.8	4.5
5	....do..	....do..	....do..	....do..	7.1	8.5	8.0	3.6	6.4	4.2	6.7	4.2
6	....do..	....do..	....do..	....do..	7.2	8.7	7.8	3.5	6.2	4.1	6.6	3.2
7	....do..	....do..	....do..	....do..	7.5	9.2	7.5	3.5	6.2	4.1	6.5	2.5
8	....do..	....do..	....do..	5.0	7.6	9.6	7.3	3.5	6.1	4.1	6.4	2.5
9	....do..	....do..	....do..	6.9	7.5	9.7	7.0	3.5	5.9	4.0	6.2	3.2
10	....do..	....do..	....do..	7.4	7.2	9.8	6.8	3.7	5.8	4.0	6.1	4.2
11	....do..	....do..	....do..	7.5	6.9	9.9	6.5	3.9	5.7	4.0	6.0	4.6
12	....do..	....do..	....do..	8.1	6.7	9.7	6.2	4.0	5.7	4.1	6.0	4.4
13	....do..	....do..	....do..	9.8	6.5	9.9	6.0	4.1	5.7	4.1	5.9	Frozen.
14	....do..	....do..	....do..	10.5	6.2	10.0	5.9	3.8	5.6	4.3	5.8	Do.
15	....do..	....do..	....do..	10 3	6.1	10.3	5.9	3.8	5.6	4.4	5.7	Do.
16	....do..	....do..	....do..	10.4	6.0	10.5	6.0	3.8	5.6	4.6	5.6	Do.
17	....do..	....do.	....do..	10.4	6.1	10.6	5.7	4.0	5.5	5.3	5.5	Do.
18	....do..	....do..	....do..	10.4	6.1	10.8	5.4	4.0	5.3	5.8	5.4	Do.
19	....do..	....do..	....do..	10.1	6.0	10.9	5.2	4.0	5.2	6.7	5.4	Do.
20	....do..	....do..	....do..	9.5	5.9	10.9	5.1	4.3	5.1	7.5	5.3	Do.
21	....do..	....do..	....do..	8.8	5.9	10.9	5.0	4.6	5.0	8.0	5.2	*a* 4.8
22	....do..	....do..	....do..	8.0	5.9	11.0	5.0	5.8	5.0	8.4	5.1	*a* 4.8
23	....do..	....do..	....do..	7.4	5.9	11.0	5.0	6.6	5.0	8.7	5.0	*a* 4.8
24	....do..	....do..	....do..	7.0	5.8	10.9	4.8	8.0	5.0	8.8	5.0	*a* 4.8
25	....do..	....do..	....do..	6.7	5.8	10.7	4.7	8.7	4.9	8.7	5.0	*a* 4.8
26	....do..	....do..	....do..	6.5	5.8	10.3	4.6	8.8	4.9	8.6	5.0	*a* 4.8
27	....do..	....do..	....do..	6.3	5.7	9.9	4.5	8.7	4.8	8.2	4.9	*a* 4.8
28	....do..	....do..	....do..	6.1	5.8	9.5	4.3	8.5	4.8	8.0	4.9	*a* 4.8
29	....do..	.....	....do..	6.1	5.8	9.2	4.2	8.3	4.7	7.8	4.8	*a* 4.6
30	....do..	.....	....do..	6.2	5.7	8.8	4.1	8.0	4.5	7.6	4.8	*a* 4.6
31	....do..	.....	....do..	.....	5.7	.....	4.0	7.7	.....	7.4	.....	*a* 4.6

a Estimated.

WEST GALLATIN RIVER AT SALESVILLE, MONTANA.

This stream has its source in the northwestern corner of Yellowstone National Park and flows in a northerly direction, joining Madison and Gallatin rivers near Threeforks to form the Missouri River. The upper 75 miles of its course is in a canyon the scenery of which rivals many of the noted canyons of Yellowstone National Park. Surveys for a road up this canyon have been made in order to reach the road system that the Government has built in the park, but the plans have not yet been carried out. About 10 miles above Salesville, Montana, the river leaves its canyon and enters the Gallatin Valley, which has an extent, in round numbers, of 1,200 square miles. This area has been noted for a number of years for its fertility; immense crops of hay and cereals are yearly matured here. The land is irrigated from canals taken from the Gallatin River and a number of tributaries, including Middle Creek, Bozeman Creek, and East Gallatin River. On certain bench lands against the sides of the surrounding mountains dry farming is practiced, or, in other words, crops are raised without irrigation. Two gaging stations are maintained on this river, one near Salesville and the other at Logan, near its mouth. The Salesville station, which has been maintained for a number of years, is located at the highway bridge crossing the stream about 5 miles south of Salesville. Kleinschmidt ditch, having a capacity of 75 second-feet but carrying of late years not over 40 second-feet, diverts water from the river above the station. A gage rod was erected in 1895 and

[1] Records kept by United States Weather Bureau.

spiked to a tree; in 1896 a wire gage was placed on the bridge, and the two gages made to read the same. The bench mark is the head of the southwest bolt in the rim of the southeast cylindrical pier, and its elevation is 13.70 feet above gage datum. The observer is Ira T. Williams, of Salesville, Montana. The results of discharge measurements are shown as follows: 1896, Eighteenth Annual Report, Part IV, page 126; 1897, Nineteenth Annual Report, Part IV, page 276; 1898, Twentieth Annual Report, Part IV, page 241. The following measurements were made under the supervision of Samuel Fortier during 1899:

March 21, gage height, 2.90 feet; discharge, 474 second-feet.
April 6, gage height, 2.80 feet; discharge, 766 second-feet.
April 13, gage height, 3.25 feet; discharge, 719 second-feet.
May 1, gage height, 3.40 feet; discharge, 830 second-feet.
May 9, gage height, 4.00 feet; discharge, 1,056 second-feet.
June 10, gage height, 5.35 feet; discharge, 2,607 second-feet.
August 30, gage height, 3.88 feet; discharge, 711 second-feet.

Daily gage height, in feet, of West Gallatin River at Salesville, Montana, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.10	2.70	.....	.....	3.30	4.70	7.30	4.60	3.80	3.50	.....	.....
2	3.10	.....	.....	2.80	3.20	5.10	7.30	4.50	3.80	3.50	.....	.....
3	3.10	.....	.....	2.80	3.10	5.50	7.30	4.50	3.80	3.50	.....	3.10
4	3.10	.....	.....	2.80	3.20	6.10	7.30	4.50	3.70	3.50	.....	.....
5	3.10	3.10	2.90	2.80	3.30	5.65	7.20	4.50	3.70	3.50	3.50	.....
6	3.10	.....	.....	2.80	3.40	5.00	7.20	4.40	3.70	3.50	.....	.....
7	3.10	.....	.....	2.90	3.50	5.00	7.10	4.40	3.70	3.50	.....	.....
8	3.10	.....	2.90	3.20	3.70	4.95	7.05	4.35	3.70	3.50	.....	.....
9	3.10	.....	.....	3.30	3.90	5.05	7.00	4.30	3.70	3.50	.....	.....
10	3.10	.....	.....	3.30	3.90	4.30	6.95	4.30	3.70	3.50	.....	3.10
11	.....	.....	.....	3.30	4.00	5.70	6.85	4.20	3.60	3.50	.....	.....
12	.....	3.10	2.90	3.30	4.10	6.05	6.75	4.20	3.60	3.50	3.50	.....
13	.....	.....	.....	3.20	4.00	6.15	6.45	4.20	3.60	3.50	.....	.....
14	.....	.....	.....	3.10	3.90	6.50	6.25	4.10	3.60	3.50	.....	.....
15	3.04	.....	.....	3.10	3.90	6.95	5.95	4.10	3.60	3.50	.....	.....
16	.....	.....	.....	3.20	3.90	7.05	5.75	4.10	3.60	3.50	.....	.....
17	.....	.....	2.90	3.10	3.85	7.25	5.55	4.10	3.60	3.50	.....	3.40
18	.....	.....	.....	3.00	3.80	7.60	5.40	4.10	3.60	3.50	.....	.....
19	3.00	3.00	2.90	3.00	3.80	8.10	5.30	4.10	3.60	3.50	3.50	.....
20	.....	.....	.....	3.00	3.80	8.55	5.30	4.10	3.60	3.50	.....	.....
21	.....	.....	.....	3.10	3.90	8.10	5.30	4.00	3.60	3.50	.....	.....
22	.....	.....	.....	3.20	4.15	7.35	5.20	3.90	3.60	3.50	.....	.....
23	.....	.....	.....	3.30	4.30	6.70	5.10	3.90	3.60	3.50	.....	.....
24	.....	.....	2.90	3.30	4.50	6.90	5.00	3.90	3.60	3.50	.....	3.30
25	2.90	.....	.....	3.30	4.55	7.00	5.00	3.90	3.60	3.50	.....	.....
26	.....	2.90	.....	3.40	4.65	7.10	4.90	3.90	3.50	3.50	3.50	.....
27	.....	.....	.....	3.50	4.55	7.20	4.85	3.90	3.50	3.50	.....	.....
28	.....	.....	.....	3.30	4.50	7.20	4.80	3.90	3.50	3.50	.....	.....
29	2.80	.....	.....	3.30	4.60	7.20	4.70	3.80	3.50	.....	.....	.....
30	.....	.....	.....	3.30	4.65	7.30	4.70	3.80	3.50	.....	.....	.....
31	.....	.....	2.80	3.30	4.70	.....	4.60	3.80	.....	.....	.....	.....

MIDDLE CREEK NEAR BOZEMAN, MONTANA.

This creek, a tributary of East Gallatin River, has its source on the northern slope of the Gallatin Range. Although it drains a small area, it is an important stream, on account of its water supply, which is used for irrigation purposes in the vicinity of Bozeman. The gaging station is located 9 miles south of Bozeman and one-eighth of a mile above the old sawmill dam in the creek canyon. Discharge measurements are made from a wire cable placed across the stream in 1898. The gage is about 200 feet below the cable, and consists of a hori-

zontal frame supporting a wire gage. Bench mark No. 1 consists of a spike driven horizontally into a stump 5 feet high about 80 feet east of the gage rod. The middle of this spike is at an elevation of 7.03 feet above gage datum. Bench mark No. 2 consists of an 8-inch bridge spike driven horizontally into a charred stump about 25 feet northeast of the gage, with an elevation of 3.58 feet. Bench mark No. 3 consists of a large rock 93 feet east of the gage, marked "B. M." in black paint, and is 4.84 feet above gage datum. Results of discharge measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 128; 1898, Twentieth Annual Report, Part IV, page 243. The following measurements were made under the direction of Samuel Fortier during 1899:

Measurements of Middle Creek near Bozeman, Montana.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Sec.-feet.*	1899.	*Feet.*	*Sec.-feet.*
Mar. 14	0.05	78	June 28	1.20	426
Apr. 4	.05	86	July 7	.98	440
Apr. 12	.05	79	July 18	.80	384
May 7	.10	92	July 26	.60	246
June 16	.90	351	Aug. 26	.15	77

Daily gage height, in feet, of Middle Creek at Bozeman, Montana, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1						0.70	1.30	0.40	0.10	0.00
2						1.20	1.10	.40	.10	.05
3	—0.25					1.10	1.00	.40	.13	.00
4						1.70	.95	.40	.10	.00
5						1.00	1.00	.40	.10	.00
6		—0.15				.80	1.00	.35	.10	.00
7			—0.05		0.20	.70	.95	.40	.10	.00
8					.20	.60	1.10	.35	.10	.08
9			— .10		.28	.70	1.00	.35	.10	.00
10					.40	.85	1.20	.30	.08	.00
11					.50	1.10	1.00	.30	.08	.00
12	.00				.43	1.20	.95	.30	.06	.00
13			— .08		.35	.90	.90	.30	.05	.00
14			— .08		.30	.80	.85	.25	.05	.00
15					.20	.80	.80	.20	.05	.00
16					.23	1.10	.80	.20		.00
17	— .10				.30	1.50	.80	.20	.04	.00
18					.28	1.60	.80	.20	.04	.00
19					.30	1.60	.95	.20	.03	.00
20					.28	1.70	.85	.20	.01	.00
21					.25	1.60	.75	.15	.01	.00
22					.23	1.40	.60	.15	.01	.00
23		— .60	— .05		.30	1.60	.55	.15	.01	.00
24	— .10				.68	1.00	.50	.15	.00	.00
25					.70	1.35	.65	.15	.00	.00
26					.65	1.35	.60	.15	.00	.00
27					.60	1.35	.60	.10	.00	.00
28		— .75	— .08		.70	1.15	.50	.10	.00	.00
29					.70	1.50	.50	.10	.00	.00
30	— .10		— .05		.50	1.30	.45	.10	.00	.00
31					.70		.40	.10		.00

GALLATIN RIVER AT LOGAN, MONTANA.

The main Gallatin River is formed by the junction of the East and West Gallatin rivers 5 miles above Logan. The wire gage is located on the east span of the railroad bridge. Bench mark No. 1 is the top

of the northeast corner of the iron plate at foot of diagonal end member of truss east end upper side, and is 13.70 feet above datum. Bench mark No. 2 consists of the head of a bridge spike driven vertically into the top of a pile stump, to which the lower end of the old incline gage is fastened; it is 0.162 foot above gage datum. Discharge measurements are made from the cable across the river 300 feet above the railroad bridge, and show the amount of water available after the diversion as above. The section is a good one, the channel being straight for some distance above and below the gaging cable. The results of measurements are published as follows: 1896, Eighteenth Annual Report, Part IV, page 129; 1897, Nineteenth Annual Report, Part IV, page 278; 1898, Twentieth Annual Report, Part IV, page 240. The following measurements were made under the direction of Samuel Fortier during 1899:

March 18, gage height, 1.00 foot; discharge, 580 second-feet.
April 9, gage height, 1.90 feet; discharge, 1,120 second-feet.
April 24, gage height, 1.60 feet; discharge, 1,089 second-feet.
May 22, gage height, 2.20 feet; discharge, 1,786 second-feet.
July 14, gage height, 3.00 feet; discharge, 1,079 second-feet.
July 30, gage height, 1.90 feet; discharge, 760 second-feet.

Daily gage height, in feet, of Gallatin River at Logan, Montana, for 1899.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	1.00	1.50	3.05	5.00	1.90	1.50	1.30	1.50	.....
2	.....	1.00	1.50	3.10	5.00	1.80	1.50	1.30	1.50	.....
3	.....	1.00	1.50	3.35	4.45	1.80	1 40	1.30	1.50	.....
4	.....	1.15	1.50	4.10	4.30	1.80	1.40	1.30	1.50	.....
5	.....	1.05	1.50	4.05	4.05	1.80	1.40	1.30	.....	.....
6	1.00	1.40	1.55	3.80	3.90	1.80	1.40	1.30	.....	1.50
7	1.20	1.80	1.60	3.45	3.75	1.80	1.40	1.30	.....	.....
8	1.35	1.95	1.65	3.25	3.55	1.80	1.40	1.30	1.50	.....
9	1.45	2.65	1.85	3.10	3.50	1.80	1.40	1.30	.....	.....
10	1.25	3.25	2.20	3.35	3.50	1.90	1.40	1.30	.....	.....
11	1.10	2.85	2.35	3.65	3.50	1.90	1.40	1.30	.....	.....
12	1.00	3.10	2.45	4.25	3.30	1.90	1.40	1.30	.....	.....
13	1.00	2.70	2.60	4.35	3.05	1.90	1.40	1.30	.....	1.60
14	1.00	2.40	2.75	4.05	3.00	1.90	1.40	1.30	.....	.....
15	1.00	1.85	2.80	3.80	2.90	1.90	1.40	1.30	1.50	.....
16	1.00	2.15	2.75	4.00	2.80	1.80	1.40	1.30	.....	.....
17	1.00	2.00	2.80	4.35	2.70	1.80	1.40	1.30	.....	.....
18	1.00	1.90	2.55	5.25	2.60	1.70	1.40	1.30	.....	.....
19	1.00	1.80	2.00	5.65	2.60	1.70	1.40	1.30	.....	.....
20	1.00	1.80	1.90	5.90	2.45	1.70	1.40	1.30	.....	1.60
21	1.10	1.50	1.90	6.25	2.40	1.70	1.40	1.30	.....	.....
22	1.10	1.75	2.05	5.60	2.40	1.70	1.40	1.30	1.50	.....
23	1.10	1.70	2.15	4.90	2.35	1.65	1.30	1.50	.....	.....
24	1.20	1.60	2.45	4.75	2.25	1.60	1.30	1.70	.....	.....
25	1.50	1.60	2.75	4.85	2.10	1.60	1.30	1.65	.....	.....
26	1.35	1.60	2.90	5.20	2.00	1.60	1.30	1.60	.....	.....
27	1.30	1.60	2.90	5.20	1.90	1.60	1.30	1.50	.....	.....
28	1.10	1.60	2.90	5.00	1.90	1.60	1.30	1.50	.....	.....
29	1.00	1.60	2.90	5.10	1.90	1.55	1.30	1.50	1.60	(a)
30	1.00	1.60	3.00	5.05	1.90	1.50	1.30	1.50	.....	.....
31	1.00	.....	3.05	.....	1.90	1.50	.....	1.50	.....	.....

January 1 to March 6 river frozen; no readings. a Frozen.

A measurement of Bridger Creek, a tributary of East Gallatin River, was made August 3 at the highway bridge at the fish hatchery in the canyon, and showed a discharge of 25 second-feet.

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DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

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No. 37

OPERATIONS AT RIVER STATIONS, 1899.—PART III

WASHINGTON
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1900

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

OPERATIONS AT RIVER STATIONS, 1899

A REPORT OF THE

DIVISION OF HYDROGRAPHY

OF THE

UNITED STATES GEOLOGICAL SURVEY

PART III

WASHINGTON

GOVERNMENT PRINTING OFFICE

1900

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OPERATIONS AT RIVER STATIONS, 1899.

PART III.

MEASUREMENTS AT RIVER STATIONS.[1]

MADISON RIVER AT REDBLUFF, MONTANA.

This river has its source in the central portion of the Yellowstone National Park, and flows in a general northerly direction, joining the Jefferson and Gallatin rivers near Threeforks to form the Missouri River. Some distance beyond the western boundary of the park an opening of considerable extent occurs, known as the Upper Madison Valley. Below Meadow Creek the bluffs close in again, and the river is in canyon to below the mouth of Cherry Creek. Beyond this it gradually opens into the lower valley. The country about the head waters of the stream is too high for profitable farming, except for summer stock ranging. Less water can be used for irrigation from this stream than from the other two tributaries of the Missouri, but the fall is admirably adapted for power purposes, and a number of surveys have been made in this connection. The gage rod, which was established May 2, 1897, is located at the ranch of the observer, Mrs. S. A. Black, 3 miles below the Redbluff iron county bridge over the Madison and about 1½ miles below the mouth of Cherry Creek. Discharge measurements are made at the highway bridge above. Cherry Creek enters between the bridge and the gage rod, and it is necessary to measure its discharge whenever a measurement of the main river is made. On June 3 its discharge was 366 second-feet, and on June 29 its discharge was 186 second-feet. Results of measurements are published as follows: 1897, Nineteenth Annual Report, Part IV, page 280; 1898, Twentieth Annual Report, Part IV, page 236. The following discharge measurements, not including Cherry Creek, were made in 1899 under the direction of Samuel Fortier:

June 3, gage height, 2.50 feet; discharge, 4,784 second-feet.
June 30, gage height, 3.30 feet; discharge, 7,616 second-feet.

[1] Continued from Water-Supply and Irrigation Paper No. 36.

Daily gage height, in feet, of Madison River at Redbluff, Montana, for 1896.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	1.65	2.60	3.65	1.70	1.40	1.30	.....	.....
2	.....	1.65	2.60	3.40	1.70	1.40	1.30	.....	.....
3	.....	1.65	2.70	3.30	1.70	1.40	1.30	1.30	.....
4	.....	1.65	2.70	3.20	1.65	1.40	1.30	.....	.....
5	.....	1.65	2.80	3.10	1.60	1.40	1.30	.....	.....
6	.....	1.65	2.70	2.90	1.70	1.40	1.30	.....	.....
7	.....	1.65	2.80	2.85	1.80	1.40	1.30	.....	(a)
8	.....	1.70	2.80	2.80	1.80	1.40	1.30	.....	.....
9	.....	1.75	2.90	2.75	1.85	1.40	1.30	.....	.....
10	.....	1.75	3.00	2.70	1.80	1.40	1.30	.....	.....
11	.....	1.80	3.10	2.60	1.75	1.40	1.30	.....	.....
12	.....	1.80	3.25	2.55	1.70	1.40	1.30	.....	.....
13	.....	1.85	3.40	2.45	1.70	1.40	1.30	.....	.....
14	.....	1.10	3.50	2.30	1.70	1.40	1.30	.....	.....
15	.....	1.10	3.70	2.30	1.70	1.40	1.30	.....	(a)
16	1.60	1.95	3.90	2.10	1.60	1.40	1.30	1.30	.....
17	1.60	1.90	3.80	2.00	1.60	1.40	1.30	.....	.....
18	1.60	1.10	3.70	1.90	1.55	1.40	1.30	.....	.....
19	1.55	1.10	3.70	1.90	1.50	1.40	1.30	.....	.....
20	1.55	1.10	3.70	1.90	1.40	1.40	1.30	.....	.....
21	1.60	1.10	3.60	1.95	1.40	1.40	1.30	.....	.....
22	1.65	1.10	3.60	2.00	1.40	1.40	1.30	.....	.....
23	1.60	1.10	3.60	2.00	1.40	1.40	1.30	1.30	.....
24	1.60	1.10	3.65	1.90	1.40	1.40	1.30	.....	.....
25	1.60	1.55	3.60	1.80	1.40	1.40	1.30	.....	.....
26	1.55	2.10	3.60	1.80	1.40	1.40	1.30	.....	.....
27	1.65	2.30	3.60	1.65	1.40	1.40	1.30	.....	.....
28	1.65	2.50	3.60	1.60	1.40	1.40	1.30	.....	(a)
29	1.65	2.50	3.65	1.60	1.40	1.40	1.30	.....	.....
30	1.65	2.50	3.70	1.70	1.40	1.40	1.30	(a)	.....
31	.....	2.60	.....	1.70	1.40	.....	1.30	.....	.....

January 1 to April 15, river frozen; no readings. a Ice.

JEFFERSON RIVER AT SAPPINGTON, MONTANA.

This river is formed by the union of Bighole and Beaverdam rivers near Twin Bridges, Montana. The former stream has its source in the highest parts of the Rocky Mountains, which form the Continental Divide and the State boundary line between Montana and Idaho. The head-water tributary of Beaverdam River is Redrock Creek, rising in in the southwestern part of the State, about 20 miles west of the boundary line of Yellowstone National Park. Jefferson River is one of the main streams that unite at Threeforks to form the Missouri River. This latter name should apply to the Jefferson and its tributary, Redrock Creek, as this is the longest of the three head-water streams of the Missouri. Irrigation is practiced to a limited extent in the upper reaches of the Jefferson, mainly for forage plants. From Twin Bridges downstream to the mouth of the North and South Boulder creeks is an extent of tillable land, which, however, has been little utilized up to the present time. The river is in canyon from Boulder Creek to about Willow Creek, whence the gorge gradually widens out into the Gallatin Valley. The station on this river is located at Sappington, 7 miles above Willow Creek, and was established by Arthur P. Davis November 13, 1894. The wire gage is fastened to the guard rail on the upper side of the Northern Pacific Railway bridge, 1 mile north of the railroad station. Bench mark No. 1 consists of a 6-inch wire nail driven horizontally in the east side of the blocking which forms the south abutment of the railroad bridge and is 6.90 feet above gage

datum. Bench mark No. 2 is a 6-inch wire nail in a telegraph pole, about 30 feet south and east of the south abutment of the bridge, and is at an elevation of 7 feet on the gage. Bench mark No. 3 is the head of the northwest bolt fastening the switch standard to the cross-tie, 30 feet east of the bridge. Its elevation is 15.67 feet. On November 3, 1897, the rod was lowered eight-tenths of a foot, the subsequent readings being adjusted to the new datum. Discharge measurements are made from a cable and car erected a short distance above the bridge. Results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 134; 1897, Nineteenth Annual Report, Part IV, page 281; 1898, Twentieth Annual Report, Part IV, page 238. The following measurements were made during 1899 by Samuel Fortier:

April 10, gage height, 2.70 feet; discharge, 2,891 second-feet.
April 24, gage height, 2.80 feet; discharge, 2,595 second-feet.
May 21, gage height, 4.50 feet; discharge, 6,505 second-feet.
July 13, gage height, 5.40 feet; discharge, 4,847 second-feet.
July 29, gage height, 3.10 feet; discharge, 2,909 second-feet.

Daily gage height, in feet, of Jefferson River at Sappington, Montana, for 1899.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	2.70	3.00	5.80	7.60	3.10	2.30	2.10	2.90	2.60
2	.....	2.70	3.00	5.80	7.55	3.00	2.30	2.10	2.80	2.60
3	.....	2.70	2.90	6.15	7.35	3.00	2.30	2.10	2.80	2.60
4	.....	2.70	2.85	7.00	7.20	2.90	2.30	2.10	2.80	2.60
5	.....	2.70	2.80	7.30	6.90	2.90	2.30	2.10	2.80	2.60
6	.....	2.70	3.05	7.40	6.70	2.90	2.30	2.10	2.80	2.60
7	.....	2.70	3.20	7.00	6.50	2.90	2.30	2.10	2.80	2.60
8	.....	2.70	3.60	6.50	6.10	2.80	2.30	2.10	2.80	2.60
9	.....	2.70	4.10	6.20	5.85	2.80	2.30	2.10	2.80	2.60
10	.....	2.70	4.55	5.95	5.65	2.80	2.30	2.10	2.80	2.60
11	.....	2.70	4.95	6.10	5.60	2.90	2.30	2.20	2.80	2.80
12	.....	2.70	5.15	6.65	5.50	3.00	2.30	2.30	2.80	2.80
13	.....	2.70	5.35	7.40	5.40	3.00	2.30	2.30	2.80	3.00
14	.....	2.70	5.25	7.80	5.40	2.95	2.30	2.40	2.80	3.60
15	.....	2.70	4.95	8.00	5.25	2.90	2.30	2.40	2.80	.....
16	.....	2.70	4.60	7.70	5.20	2.80	2.30	2.50	2.80	.....
17	.....	2.70	4.25	7.30	4.85	2.80	2.30	2.50	2.80	.....
18	.....	3.00	4.40	7.40	4.75	2.70	2.30	2.60	2.80	.....
19	.....	2.90	4.50	7.85	4.60	2.60	2.30	2.70	2.80	.....
20	.....	2.85	4.60	8.50	4.45	2.60	2.30	2.70	2.80	.....
21	.....	2.70	4.45	9.00	4.35	2.60	2.30	2.80	2.70	.....
22	.....	2.70	4.40	9.60	4.25	2.60	2.30	2.90	2.70	.....
23	.....	2.70	4.40	9.65	4.05	2.60	2.30	2.90	2.60	.....
24	.....	2.70	4.50	9.10	3.85	2.80	2.30	2.90	2.60	.....
25	.....	2.70	4.65	8.30	3.65	2.80	2.30	2.90	2.60	.....
26	.....	2.80	5.35	8.00	3.45	2.80	2.20	2.90	2.60	.....
27	.....	3.00	5.65	8.00	3.25	2.70	2.20	2.90	2.60	.....
28	.....	3.15	5.90	7.80	3.10	2.70	2.20	2.90	2.60	.....
29	2.70	3.20	5.90	7.60	3.10	2.50	2.10	2.90	2.60	.....
30	2.70	3.10	5.80	7.70	3.10	2.50	2.10	2.90	2.60	.....
31	2.70	.....	5.80	.....	3.10	2.40	.....	2.90	.....	.....

January 1 to March 28, river frozen: no readings.
December 15 to 31, river frozen; no readings.

MISSOURI RIVER AT TOWNSEND, MONTANA.

This river is formed by the junction of the Jefferson, Madison, and Gallatin rivers at Threeforks, Montana. Observations of gage heights are maintained at Townsend by the Missouri River Commission, and although the section is not an ideal one, it still seems desirable to make occasional discharge measurements as the station is easily accessible and daily gage observations are taken at no expense to this Survey. The gage is located at the wagon bridge about a mile north of the railroad station. The heights given are the means of two daily readings expressed in feet above the St. Louis directrix, which is 412.73 feet above mean gulf level. In the following table, furnished by Charles Keller, first lieutenant, Corps of Engineers, United States Army, the figures 3,300 have been omitted, and it is therefore necessary to add this amount to obtain the elevation of the water surface above the St. Louis datum. Results of measurements are found as follows: 1896, Eighteenth Annual Report, Part IV, page 124; 1897, Nineteenth Annual Report, Part IV, page 283; 1898, Twentieth Annual Report, Part IV, page 244. The following discharge measurements were made during 1899 under the direction of Samuel Fortier:

May 30, gage height, 92.00; discharge, 13,021 second-feet.
June 15, gage height, 93.80 feet; discharge, 29,832 second-feet.
July 21, gage height, 90.90 feet; discharge, 8,842 second-feet.

Daily gage height, in feet, of Missouri River at Townsend, Montana, for 1899.

Day.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	90.10	91.90	94.10	89.90	89.15	88.90	89.30	89.30
2	.....	89.90	92.20	94.05	89.90	89.10	88.90	89.30	89.30
3	.....	89.80	92.40	93.95	89.85	89.10	89.00	89.30	89.30
4	88.40	89.80	92.85	93.60	89.80	89.10	89.00	89.30	89.10
5	88.50	89.80	93.35	93.35	89.70	89.10	89.05	89.35	89.00
6	88.80	89.80	93.50	93.05	89.70	89.10	89.00	89.35	89.05
7	89.30	89.90	93.30	92.80	89.70	89.05	89.00	89.35	89.10
8	89.80	90.30	93.10	92.60	89.75	89.00	89.00	89.35	89.10
9	89.90	90.60	92.60	92.55	89.80	89.00	89.00	89.35	89.10
10	90.20	91.05	92.30	92.45	89.95	89.00	89.10	89.35	89.10
11	90.40	91.25	92.45	92.35	89.95	89.00	89.10	89.35	a 89.10
12	90.55	91.55	92.80	92.25	89.90	89.00	89.15	89.40	89.10
13	90.85	91.70	93.40	92.05	89.85	89.00	89.20	89.40	89.10
14	90.45	91.60	93.70	92.00	89.80	89.05	89.20	89.40	89.10
15	90.00	91.60	93.75	91.80	89.70	89.10	89.20	89.40	89.10
16	90.00	91.50	93.75	91.65	89.65	89.15	89.20	89.40	a 89.10
17	90.05	91.35	93.60	91.50	89.55	89.10	89.20	89.45	89.10
18	89.95	91.25	93.70	91.20	89.50	89.10	89.20	89.45	89.10
19	89.90	91.15	94.10	91.05	89.50	89.10	89.30	89.45	89.15
20	89.75	91.10	94.60	90.95	89.50	89.10	89.40	89.45	89.20
21	89.70	91.10	95.20	90.90	89.45	89.00	89.45	89.40	89.25
22	89.90	91.05	95.35	90.85	89.50	89.00	89.50	89.30	89.20
23	90.00	91.00	95.65	90.70	89.50	89.00	89.55	89.25	89.20
24	89.95	91.00	95.75	90.60	89.50	89.05	89.60	89.20	89.30
25	89.95	91.05	95.25	90.40	89.45	89.00	89.65	89.20	89.40
26	90.15	91.40	94.55	90.30	89.40	89.00	89.50	89.20	89.50
27	90.40	91.60	94.40	90.10	89.40	89.00	89.50	89.15	89.55
28	90.20	92.05	94.45	90.05	89.30	88.95	89.50	89.20	89.65
29	90.10	92.00	94.20	90.00	89.20	88.90	89.40	89.20	b 91.70
30	90.10	92.00	94.20	90.00	89.20	88.90	89.40	89.25	90.90
31	.....	91.95	.....	89.95	89.20	.....	89.40	.....	90.90

a Ice readings, December 11 to 16.

b Ice gorged December 29.

MILK RIVER AT HAVRE, MONTANA.

This river rises on the eastern slope of the Rocky Mountains in the extreme northern part of Montana. The head-water tributaries have a general northeasterly direction, crossing the international boundary line into British territory, in which there is a large area drained. The river reenters the United States farther eastward and flows in a general southerly direction to Havre. Its course is thence easterly until it joins the Missouri River near Glasgow, Montana, at the southwestern corner of Fort Peck Indian Reservation. The valley of this river is fertile and well adapted for raising the hardier grains. Development in this direction has been somewhat slow until within the past few years. The area drained by Milk River is to a large extent rolling prairie lands, excellent for grazing purposes and covered with a good growth of grass. The discharge measurements show the amount of water available for the canals, a number of which have recently been taken from the river below Havre, as described in the Eighteenth Annual Report, Part IV, page 286. The present station is located at Havre, Montana, and was established by Cyrus C. Babb, May 15, 1898. The gage rod is an especial form described in Water-Supply Paper No. 27, page 68. Measurements of discharge are made from a car and cable of 200-foot span swung across the river a short distance above the gage. The river is subject to violent floods of short duration, and the bed of the river being composed of gravels and clay is liable to change after each freshet. Results of measurements for 1898 are shown in the Eighteenth Annual Report, Part IV, page 245. The following discharge measurements were made by C. W. Ling in 1899:

Measurements of Milk River at Havre, Montana.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Sec.-ft.*	1899.	*Feet.*	*Sec.-ft.*
Apr. 20	3.20	1,410	July 31	1.00	228
Apr. 28	2.20	807	Aug. 3	1.10	252
May 8	1.90	732	Aug. 5	1.40	379
May 12	2.60	1,087	Aug. 11	.80	182
May 16	2.50	911	Aug. 16	.50	111
May 22	3.50	1,657	Aug. 19	.40	106
May 29	3.40	1,653	Aug. 25	.60	137
June 3	2.90	1,126	Aug. 28	.80	158
June 10	2.80	1,209	Sept. 2	.60	127
June 15	2.30	661	Sept. 7	.30	99
June 20	2.00	586	Sept. 12	.20	88
June 28	1.90	588	Sept. 15	.30	96
July 3	1.40	353	Sept. 21	1.50	360
July 7	1.20	298	Sept. 25	1.90	221
July 11	1.25	314	Sept. 30	1.50	122
July 17	.80	181	Oct. 16	1.40	109
July 22	.60	150	Oct. 24	1.70	146
July 27	.70	170	Nov. 6	2.40	368

Daily gage height, in feet, of Milk River at Havre, Montana, for 1899.

Day.	Jan.	Feb.	Apr.	May.	Sept.	Oct.	Nov.	Dec.
1				2.00	0.60	1.40	1.30	
2	1.40			1.90	.60	1.30	1.30	
3				1.90	.50	1.40	1.30	(a)
4		1.80		1.90	.50	1.30	1.30	
5				1.90	.40	1.30	2.40	
6				2.50	.40	1.20	2.40	
7	1.40			2.60	.30	1.10		
8				2.60	.40	1.30		
9	1.40			2.50	.40	1.30		
10				2.50	.30	1.30		(a)
11				2.50	.30	1.20		
12				2.50	.20	1.00	2.20	
13				2.55	.20			
14	1.40			2.60	.20			
15				2.60	.30	1.30		
16			4.60	2.60	.20	1.30		
17			4.30	2.60	.40	1.20		(a)
18			3.90	2.70	1.50	1.10		
19		1.90	3.40	2.70	1.60	1.10	1.10	
20		2.50	3.20	2.70	1.10	1.10		
21	1.80		3.20	2.70	1.90	1.00		
22			3.05	2.95	2.00	1.20		
23			2.80	3.30	2.00	1.10		
24	1.80		2.55	3.20	1.90	1.10		(a)
25			2.50	3.20	1.80	1.00		
26			2.50	2.70	1.70	1.30		
27			2.40	2.80	1.60	1.30	1.90	
28	1.80		2.25		1.40	1.40		
29			2.20		1.50	1.40		
30			2.00		1.60	1.40		
31						1.30		

a Frozen.

YELLOWSTONE RIVER AT LIVINGSTON, MONTANA.

This river has its source in Yellowstone Lake, in the National Park, and flows in a northerly direction into Montana. Its course is thence easterly to its junction with the Missouri River, near the North Dakota line. Owing to the fact of the numerous springs of the park which contribute to its flow, and also to the fact that the lake acts as a regulator, the discharge when it crosses the Montana line is large for a river of this section of the country. Yellowstone Valley is the largest body of irrigable land in Montana, having a length of about 500 miles. At the present time it is principally utilized as a range for a vast number of cattle and sheep. With its comparatively low altitude of 2,500 feet, the section is well adapted for the future development of irrigation. The gaging station established May 2, 1897, is located at the highway bridge over the Yellowstone River, 5 miles south of Livingston, at the mouth of the canyon. A wire gage is in use. A new bench mark was established in 1899, as follows: The top of the end plate of bridge at upper side of east end, at an elevation of 14.20 feet above zero of gage. The slope of the water surface at gaging station was found to be 0.146 feet in 200 feet on August 29, 1899. The observer is Thomas S. Carter, who lives at the end of the bridge. The results of measurements may be found as follows: 1897, Nineteenth Annual Report, Part IV, page 289; 1898, Twentieth

Annual Report, Part IV, page 248. The following measurements of discharge were made under the direction of Samuel Fortier in 1899:

March 10, gage height, 1.00 foot; discharge, 1,702 second-feet.
March 24, gage height, 1.10 feet; discharge, 1,801 second-feet.
April 5, gage height, 1.10 feet; discharge, 1,868 second-feet.
April 14, gage height, 1.40 feet; discharge, 2,629 second-feet.
May 28, gage height, 3.70 feet; discharge, 6,964 second-feet.
June 21, gage height, 8.00 feet; discharge, 22,053 second-feet.
July 20, gage height, 5.30 feet; discharge, 7,283 second-feet.
August 29, gage height, 1.86 feet; discharge, 5,337 second-feet.

Daily gage height, in feet, of Yellowstone River at Livingston, Montana, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	------	------	0.85	0.90	1.60	4.20	7.88	4.10	1.70	0.55	------	------
2	------	------	.85	.95	1.53	4.35	7.58	4.00	1.70	.50	0.05	------
3	------	(a)	.85	.95	1.43	5.03	7.30	3.90	1.70	.45	------	—0.30
4	------	------	.90	1.00	1.40	5.40	7.15	3.80	1.68	.43	.05	------
5	0.60	------	.90	1.10	1.40	5.35	7.08	3.70	1.60	.40	------	------
6	------	------	.90	1.10	1.48	4.85	7.00	3.70	1.48	.40	------	------
7	------	------	.90	1.10	1.60	4.48	6.93	3.60	1.40	.40	------	------
8	------	------	.95	1.10	1.80	4.38	6.95	3.50	1.33	.38	------	------
9	------	------	1.00	1.13	2.25	4.35	6.95	3.50	1.30	.35	------	— .80
10	------	------	1.00	1.30	2.73	5.00	6.75	3.63	1.28	.35	------	------
11	------	------	.80	1.30	3.00	5.50	6.65	3.35	1.20	.35	.00	------
12	.70	------	.85	1.30	3.30	6.20	6.55	3.25	1.15	.35	------	------
13	------	.70	.90	1.50	3.40	5.60	6.20	3.10	1.15	.35	------	------
14	------	------	.85	1.43	3.10	5.28	5.93	3.03	1.15	.35	------	------
15	------	------	.80	1.25	2.90	5.20	5.75	2.98	1.15	.35	------	------
16	------	------	.85	1.38	2.75	5.63	5.65	2.83	1.10	.30	------	(a)
17	------	.85	.95	1.40	2.58	6.68	5.55	2.73	1.03	.30	------	------
18	------	------	.95	1.35	2.53	7.60	5.38	2.70	1.00	.30	— .10	------
19	------	------	.93	1.28	2.70	8.05	5.30	2.65	.93	.30	------	------
20	------	------	.90	1.23	2.90	8.55	5.28	2.53	.90	.40	------	------
21	.90	------	(a)	1.20	2.90	8.30	5.28	2.43	.85	.35	------	------
22	------	------	.88	1.35	2.80	7.15	5.13	2.40	.83	.43	------	------
23	------	------	.93	1.50	2.75	6.73	4.85	2.35	.75	.43	------	— .50
24	------	.80	1.05	1.55	3.13	6.95	4.68	2.28	.73	.40	------	------
25	------	------	1.15	1.80	4.03	7.25	4.60	2.18	.70	.35	— .35	------
26	.90	------	1.05	2.00	4.35	7.60	4.50	2.10	.70	.23	------	------
27	------	------	.78	1.95	3.95	7.60	4.48	1.98	.70	.20	------	------
28	------	------	.90	1.78	3.85	7.60	4.30	1.90	.65	.18	------	------
29	------	------	1.00	1.63	4.00	7.78	4.30	1.83	.60	.15	------	------
30	------	------	1.00	1.60	4.25	8.05	4.30	1.80	.58	.15	------	— .80
31	------	------	.90	------	4.20	------	4.15	1.75	------	.10	------	------

a Frozen.

BIGHORN RIVER AT THERMOPOLIS, WYOMING.

A number of discharge measurements were made on this river at Thermopolis, Wyoming, by A. J. Parshall, during the progress of a survey in that vicinity, which he had undertaken for the State. A bench mark was established on the pile near the ferry, and the gage heights noted are the distance of water surface below this bench mark; they are, therefore, in reverse order to the usual records of water heights. Four measurements were made during 1899, as follows:

July 28, gage height, 8 feet below bench mark; discharge, 4,867 second-feet.
August 7, gage height, 8.38 feet below bench mark; discharge, 4,204 second-feet.
August 16, gage height, 8.98 feet below bench mark; discharge, 2,673 second-feet.
September 14, gage height, 9.74 feet below bench mark; discharge, 1,162 second-feet.

SHOSHONE RIVER AT LOVELL, WYOMING.

The source of this river is in the high mountain peaks along the eastern border of the Yellowstone National Park. It has a general northeasterly course and enters Bighorn River about 12 miles above the Montana State line. Irrigation is practiced to a limited extent in the upper headwaters, but principally from the small tributaries, as Trout, Rattlesnake, and Cottonwood creeks. Below the junction of the North and South forks a number of large irrigation enterprises have recently been undertaken. A gaging station was established May 23, 1897, at Lovell, Wyoming. The rod is fastened to the landing pier of the ferry on the south side of the river. The channel is straight for some distance above and below the rod, and the cross section at the gaging point has a uniform depth. The bed of the river is stable. The results of measurements are shown as follows: 1897, Nineteenth Annual Report, Part IV, page 292; 1898, Twentieth Annual Report, Part IV, page 249. No discharge measurements were made at this station during 1899.

Daily gage height, in feet, of Shoshone River at Lovell, Wyoming, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Day.	Apr.	May.	June.	July.	Aug.	Sept.
1	.....	—.80	0.60	3.80	+0.20	—1.10	17	— .90	—.40	3.00	2.60	— .50	—1.50
2	.....	—.80	.60	3.60	+ .60	—1.10	18	— .80	—.40	3.90	2.60	— .50	—1.50
3	.....	—.70	3.00	3.40	— .10	—1.20	19	— .70	—.40	4.30	2.70	— .60	—1.50
4	.....	—.70	.60	3.20	— .30	—1.20	20	— .60	+.10	4.20	2.60	— .60	—1.50
5	.....	—.70	.30	3.20	— .20	—1.20	21	— .40	.30	4.00	2.50	— .70	—1.50
6	.....	—.50	.90	3.10	— .30	—1.20	22	— .20	.20	2.70	2.50	— .80	—1.50
7	.....	—.50	.70	3.10	— .20	—1.20	23	.00	.10	2.50	2.50	— .90	—1.50
8	.....	—.40	.50	3.00	— .30	—1.30	24	+ .70	.50	2.50	1.40	— .90	—1.50
9	.....	—.20	.90	3.20	— .30	—1.30	25	+ .60	.90	2.90	1.40	— .90	—1.50
10	.....	+.20	1.30	2.90	— .30	—1.80	26	— .60	.70	3.50	1.00	—1.00	—1.50
11	.....	.30	2.00	2.80	— .30	—1.40	27	— .70	.70	3.30	1.00	—1.00	—1.50
12	—0.80	.30	2.80	2.70	— .30	—1.40	28	— .70	.80	3.40	1.40	—1.00	—1.50
13	— .90	.20	2.00	2.80	— .30	—1.40	29	— .70	.70	3.70	1.30	—1.00	—1.50
14	— .90	—.10	1.50	2.90	— .30	—1.40	30	— .70	.80	4.00	1.70	—1.00	—1.50
15	— .80	—.40	1.40	2.70	— .40	—1.40	31	.....	.70	.....	1.10	—1.00	.....
16	— .80	—.20	2.20	2.60	— .40	—1.40							

CLEAR CREEK AT BUFFALO, WYOMING.

This creek is one of the most important tributaries of Powder River, having its source in the summit of the Bighorn Mountains. The irrigating system diverting water from this stream has been described in detail in earlier reports. The point of measurement is about 4 miles west of Buffalo, Wyoming, at which point is a flume erected in 1889. Of late years this station is not considered as important as formerly, on account of the diversions of water which have taken place within its basin. The earlier discharge measurements established a rating for the measuring flume, and it has not been necessary to make any since. The results of measurements are shown as follows: 1896, Eighteenth Annual Report, Part IV, page 140; 1897, Nineteenth Annual Report, Part IV, page 298; 1898, Twentieth Annual Report,

Part IV, page 250. No measurements of discharge were made at this point during 1899.

Daily gage height, in feet, of Clear Creek at Buffalo, Wyoming, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.80				0.60	1.13	1.80	1.35	0.50	0.48	0.50	
2					.50	1.18	1.53	1.27	.49	.50	.45	
3					.50	1.63	1.47	1.18	.47	.49	.43	0.45
4				0.30	.50	1.37	1.46	1.15	.57	.50	.42	
5		0.25	0.25		.45	1.34	1.46	1.12	.57	.49	.42	
6					.52	1.24	1.45	1.03	.58	.49	.48	
7					.73	1.20	1.40	.94	.57	.50	.47	
8	.33				.52	1.15	1.43	.81	.57	.50	.48	
9					.54	1.14	1.41	.70	.56	.57	.49	
10					.67	1.11	1.42	.73	.56	.56	.47	.40
11					.58	1.26	1.39	.69	.50	.56	.48	
12			.30	.40	.64	1.34	1.33	.64	.50	.57	.47	
13					.70	1.39	1.39	.60	.50	.59	.49	
14					.60	1.26	1.37	.59	.50	.58	.50	
15	.30				.69	1.23	1.39	.59	.60	.59	.47	
16					.70	1.23	1.35	.58	.50	.60	.48	
17					.69	1.40	1.20	.56	.48	.60	.48	.40
18					.70	2.15	1.20	.57	.62	.60	.49	
19		.25		.60	.77	2.43	1.25	.53	.61	.59	.49	
20					1.17	2.42	1.21	.54	.61	.58		
21					1.20	2.45	1.23	.58	.60	.56		
22					.90	1.75	1.23	.57	.58	.53		
23					.90	1.45	1.44	.55	.52	.57		
24					1.10	1.46	1.75	.53	.54	.55		.40
25					1.24	1.89	1.73	.52	.51	.44		
26		.25			1.20	2.07	1.73	.50	.50	.42	.45	
27					1.13	1.73	1.70	.50	.51	.49		
28					1.12	1.64	1.70	.49	.50	.48		
29					1.12	1.72	1.58	.48	.49	.47		.40
30				.63	1.21	1.87	1.42	.49	.49	.39		
31					1.14		1.42	.49		.48		

MINNECHADUSA RIVER AT VALENTINE, NEBRASKA.

This stream rises in South Dakota, flows into Nebraska, and empties into Niobrara River near Valentine. Measurements have been made at the times when the regular river station on Niobrara River at Fort Niobrara has been visited. The results are of value as showing the flow available for milling purposes, there being little, if any, opportunity for irrigation. Measurements were made by Glenn E. Smith at a point 1 mile above the town. The channel at this point is straight, and the water moves with moderate velocity. The banks are high and the bed sandy. Most of the measurements were made by wading. Results for 1899 are as follows:

January 27, 26.2 second-feet; February 21, 45.0 second-feet; March 15, 25.7 second-feet; April 26, 32.6 second-feet; May 11, 35.6 second-feet; June 23, 23.0 second-feet; August 12, 19.0 second-feet; September 13, 23.5 second-feet; September 26, 26.5 second-feet; October 20, 30.0 second-feet.

NIOBRARA RIVER AT FORT NIOBRARA, NEBRASKA.

This river rises in eastern Wyoming and flows across the State line into Nebraska, continuing along the northern side of that State near the boundary of South Dakota until it enters the Missouri River at the northeastern corner of Nebraska. A gaging station was estab-

lished by O. V. P. Stout on July 22, 1897, three-fourths of a mile southwesterly from Fort Niobrara and above the mouth of Minnechadusa River. It was afterwards discontinued, but was resumed on April 26, 1899, when a rod was located 195 feet downstream from the wagon bridge near Fort Niobrara. The rod is solidly bedded on cross-ties and well fastened with bridge spikes. It is a new 3 by 4 inch oak rod 10 feet long, and is placed on the left bank of the stream. Bench mark No. 1 is the top of a large spike driven in the top of a 2 by 4 inch timber which is set 4 feet in the ground and 12 feet west of the rod, and is 5.63 feet above gage datum. Bench mark No. 2 is the top of the short cap at shoe of truss at west end of the bridge, downstream side, and is 9.98 feet above the zero of the gage. Bench mark No. 3 is the top of the plate of the center pier of the bridge, downstream side, and is 10.03 feet above gage datum. Thomas Dillon, mail carrier between Valentine and Fort Niobrara, is the observer. The results of measurement are shown as follows: 1897, Nineteenth Annual Report, Part IV, page 300; 1898, Twentieth Annual Report, Part IV, page 255. The following discharge measurements were made by Glenn E. Smith during 1899:

Measurements of Niobrara River at Fort Niobrara, Nebraska.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Second-ft.*	1899.	*Feet.*	*Second-ft.*
Jan. 27	Frozen.	623	July 16	1.52	788
Mar. 15	Frozen.	726	Aug. 13	1.30	718
Mar. 15	Frozen.	a 650	Aug. 30	1.35	700
Apr. 25	1.15	952	Sept. 13	1.15	695
May 11	1.18	867	Sept. 26	1.05	732
May 26	1.44	1,031	Oct. 7	1.15	776
June 23	1.24	733	Oct. 20	0.80	849

a Measurement made at point 5 miles south of Valentine.

Daily gage height, in feet, of Niobrara River at Fort Niobrara, Nebraska, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Day.	Apr.	May.	June.	July.	Aug.	Sept.
1	.....	1.13	1.31	1.21	1.31	1.24	17	.....	1.12	1.41	1.51	1.41	1.24
2	.....	1.11	1.31	1.41	1.34	1.24	18	.....	1.14	1.41	1.44	1.44	1.21
3	.....	1.12	1.34	1.34	1.51	1.31	19	.....	1.21	1.34	1.41	1.41	1.14
4	.....	1.12	1.31	1.23	1.41	1.31	20	.....	1.22	1.24	1.41	1.34	1.14
5	.....	1.14	1.31	1.24	1.34	1.24	21	.....	1.23	1.23	1.41	1.32	1.24
6	.....	1.21	1.21	1.34	1.34	1.21	22	.....	1.24	1.23	1.31	1.34	1.21
7	.....	1.13	1.14	1.41	1.31	1.21	23	.....	1.34	1.22	1.31	1.34	1.11
8	.....	1.24	1.12	1.41	1.31	1.21	24	.....	1.44	1.22	1.31	1.34	1.11
9	.....	1.31	1.12	1.41	1.41	1.24	25	.....	1.34	1.51	1.24	1.24	1.14
10	.....	1.14	1.12	1.42	1.34	1.21	26	1.14	1.44	1.21	1.21	1.24	1.12
11	.....	1.14	1.24	1.44	1.31	1.21	27	1.14	1.41	1.31	1.24	1.24	1.14
12	.....	1.14	1.44	1.44	1.34	1.14	28	1.21	1.42	1.34	1.24	1.24	1.11
13	.....	1.14	1.34	1.51	1.41	1.14	29	1.21	1.41	1.34	1.31	1.31	1.11
14	.....	1.14	1.21	1.42	1.21	1.14	30	1.13	1.42	1.41	1.31	1.31	1.11
15	.....	1.14	1.21	1.51	1.31	1.24	31	.....	1.31	.....	1.31	1.21	.....
16	.....	1.11	1.24	1.54	1.41	1.21							

LARAMIE RIVER AT WOODS LANDING, WYOMING.

This river, a tributary of the North Platte River, entering it at Fort Laramie, Wyoming, has its source in the mountains of northern Colorado, adjoining the head waters of the Cache la Poudre on the west.

Irrigation is practiced on a small scale in Colorado, but principally for hay ranches, as the elevation is too great for diversified farming. One important diversion—that of the Sky-line canal—takes water from the Laramie, carrying it across the divide and into Cache la Poudre drainage. This diversion is working a hardship to the Wyoming appropriators below, as many in this State have prior rights to Sky-line canal, but owing to the present water laws the Wyoming rancher has no redress through the courts. Laramie River, on crossing the Wyoming line, soon leaves its canyon and enters the Laramie Plains, which are extensively irrigated from the main stream and from the various tributaries, notably from Little Laramie River, whose low-water flow is now entirely used. Lower down on its course the river passes through another canyon, to enter finally the plain of the Lower Laramie, which extends from the eastern edge of the Laramie Hills to the mouth of the river. A notable diversion in this section of the country is that of the Wyoming Development Company, taking water from Laramie River about 27 miles southwest of Wheatland. This canal system is more fully described in the Nineteenth Annual Report, Part IV, page 303. Two gaging stations are maintained on the river, one at Woods Landing, a short distance after the river appears in Wyoming, and the other at Uva, near its mouth. The former station is 26 miles from Laramie, Wyoming, and is reached by stage. Measurements of discharge are made from the wagon bridge which spans the river at this point.

The gage rod is fastened to a perpendicular post set firmly in the bed of the stream and braced at the top to adjacent trees, and is about 400 feet above the bridge. The bench mark is a nail in a notch on a cottonwood tree 1 foot in diameter, 6 feet from the rod, and is on a level with the 7-foot mark on the rod. The measurements here show the amount of water available for the use of the irrigators below. The bottom of the stream is composed of large granite bowlders, which renders the shape and slope of the channel practically unchangeable, but adds an element of uncertainty to the gaging results, owing to the difficulty of determining the correct cross section. Results of measurements are published as follows: 1896, Eighteenth Annual Report, Part IV, page 147; 1897, Nineteenth Annual Report, Part IV, page 302; 1898, Twentieth Annual Report, Part IV, page 274. The following measurements of discharge were made by A. J. Parshall in 1899:

May 26, gage height, 3.30 feet; discharge, 2,598 second-feet.
June 8, gage height, 3.10 feet; discharge, 2,319 second-feet.
June 21, gage height, 4.40 feet; discharge, 4,145 second-feet.
July 6, gage height, 2.80 feet; discharge, 2,194 second-feet.

Daily gage height, in feet, of Laramie River at Woods Landing, Wyoming, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	.....	2.00	2.00	1.20	3.15	3.75	1.40	0.80	0.40	.....	.....
2	.....	.....	.....	2.00	1.10	3.25	3.65	1.40	0.75	0.40	.....	.....
3	2.00	2.00	.....	2.00	1.00	3.25	3.50	1.55	0.75	0.40	.....	.....
4	.....	.....	.....	2.00	1.00	3.15	3.50	1.70	0.70	0.40	.....	.....
5	.....	.....	.....	2.00	1.00	2.95	3.10	1.75	0.60	0.50	.....	.....
6	.....	.....	.....	2.00	1.20	3.05	2.80	1.70	0.60	0.50	.....	.....
7	.....	.....	.....	2.00	1.30	3.00	2.70	1.60	0.60	0.65	0.60	0.90
8	.....	.....	2.00	2.00	1.40	3.00	2.60	1.50	0.50	0.75	.....	.....
9	.....	.....	.....	2.00	1.50	3.00	2.45	1.40	0.50	0.80	.....	.....
10	2.10	2.00	.....	2.00	1.60	3.05	2.35	1.35	0.50	0.85	.....	.....
11	.....	.....	.....	2.00	1.75	3.45	2.50	1.20	0.55	0.80	.....	.....
12	.....	.....	.....	2.00	1.95	3.80	2.65	1.10	0.50	0.80	.....	.....
13	.....	.....	.....	2.00	2.30	4.30	2.65	1.10	0.50	0.70	.....	.....
14	.....	.....	.....	2.00	2.55	4.35	2.55	1.08	0.50	0.70	0.70	1.10
15	.....	.....	2.00	2.00	2.60	3.75	2.45	1.00	0.60	0.70	.....	.....
16	.....	.....	.....	2.00	2.65	3.50	2.30	1.00	0.65	0.70	.....	.....
17	2.00	2.00	.....	1.90	2.55	3.75	2.20	0.90	0.60	0.70	.....	.....
18	.....	.....	.....	1.90	2.45	3.85	2.05	0.90	0.60	0.70	.....	.....
19	.....	.....	.....	1.80	2.60	3.95	2.00	0.90	0.60	0.60	.....	.....
20	.....	.....	.....	1.80	2.65	4.15	1.85	0.90	0.60	0.70	.....	.....
21	.....	.....	.....	1.70	2.75	4.25	1.80	0.85	0.50	0.75	0.70	1.00
22	.....	.....	2.00	1.70	2.85	4.45	1.85	0.80	0.50	0.70	.....	.....
23	.....	.....	.....	1.60	2.95	4.50	1.80	0.80	0.50	0.70	.....	.....
24	2.00	.....	.....	1.50	3.10	4.40	1.80	0.80	0.50	0.60	.....	.....
25	.....	2.00	.....	1.50	3.20	4.65	1.75	0.78	0.50	0.60	.....	.....
26	.....	.....	.....	1.40	3.20	4.55	1.75	0.75	0.40	0.60	.....	.....
27	.....	.....	.....	1.40	3.10	4.40	1.75	0.70	0.40	0.60	.....	.....
28	.....	.....	.....	1.30	3.25	4.15	1.90	0.60	0.40	0.60	0.80	1.20
29	.....	.....	.....	1.20	3.35	4.05	1.75	0.60	0.40	8.60	.....	.....
30	.....	.....	.....	1.15	3.30	3.90	1.60	0.75	0.50	0.60	.....	.....
31	.....	.....	.....	.....	3.05	.....	1.45	0.90	.....	0.60	.....	.....

LARAMIE RIVER AT UVA, WYOMING.

This station is located 18 miles, by wagon road, from the mouth of the river at Fort Laramie, and the results obtained show practically the amount of water passing out of the State from this drainage area. The rod is fastened to the railroad bridge of the Cheyenne Northern Railway, a half mile from the town of Uva, while discharge measurements are made from the wagon bridge 1,000 feet below. The bench mark is a spike head on the south side of a pile on the east end of railroad bridge, and is 11.95 feet above zero of gage. The bed of the river is sandy and liable to change during high water. The results of measurements are shown as follows: 1896, Eighteenth Annual Report, Part IV, page 149; 1897, Nineteenth Annual Report, Part IV, page 302; 1898, Twentieth Annual Report, Part IV, page 176. The following measurements of discharge were made by A. J. Parshall in 1899:

April 25, gage height, 3 feet; discharge, 863 second-feet.
May 6, gage height, 2.80 feet; discharge, 530 second-feet.
May 30, gage height, 4.40 feet; discharge, 2,022 second-feet.
June 13, gage height, 4.50 feet; discharge, 2,144 second-feet.
June 26, gage height, 5.80 feet; discharge, 3,472 second-feet.
July 13, gage height, 3.95 feet; discharge, 1,607 second-feet.

Daily gage height, in feet, of Laramie River at Uva, Wyoming, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.80	1.40	1.50	1.50	3.00	4.60	5.30	2.20	1.20	0.90	.....	.....
2	.....	.....	.....	1.50	2.90	4.70	5.30	2.20	1.20	0.90	.....	1.50
3	.....	.....	.....	1.40	2.90	4.80	5.00	2.20	1.20	0.90	.....	.....
4	.....	.....	.....	1.40	2.80	4.80	4.90	2.10	1.20	0.90	1.60	.....
5	.....	.....	.....	1.50	2.80	4.80	5.00	2.10	1.20	0.90	.....	.....
6	.....	.....	.....	1.60	2.80	4.80	5.10	2.10	1.20	0.90	.....	.....
7	.....	.....	1.50	1.80	2.80	4.70	4.90	2.00	1.20	0.90	.....	.....
8	1.00	1.40	.....	1.80	2.60	4.60	4.70	2.00	1.20	0.90	.....	.....
9	.....	.....	.....	2.00	2.40	4.20	4.70	2.00	1.60	1.00	.....	1.40
10	.....	.....	.....	3.00	2.20	4.10	4.60	2.00	1.50	1.10	.....	.....
11	.....	.....	.....	3.40	2.00	4.10	4.40	2.00	1.40	1.20	1.40	.....
12	.....	.....	.....	5.60	1.90	4.20	4.20	1.90	1.30	1.20	.....	.....
13	.....	.....	.....	5.10	1.90	4.30	4.20	1.90	1.10	1.20	.....	.....
14	.....	.....	1.60	5.40	1.80	4.30	4.10	1.90	1.10	1.30	.....	.....
15	1.00	1.50	.....	4.80	1.80	4.80	4.00	1.90	1.10	1.30	.....	.....
16	.....	.....	.....	4.40	2.55	5.00	4.00	2.00	1.10	1.30	.....	2.00
17	.....	.....	.....	4.30	3.40	5.50	4.00	2.00	1.00	1.30	.....	.....
18	.....	.....	.....	4.20	3.40	5.50	3.80	2.00	1.00	1.30	1.50	.....
19	.....	.....	.....	3.20	3.30	5.60	3.60	2.00	1.00	1.30	.....	.....
20	.....	.....	.....	3.60	4.80	5.60	3.50	1.90	1.00	1.40	.....	.....
21	.....	.....	1.60	3.00	4.80	5.60	3.30	1.90	1.00	1.40	.....	.....
22	1.40	1.50	.....	3.00	4.50	5.50	3.10	1.80	1.00	1.40	.....	.....
23	.....	.....	.....	3.30	4.40	5.50	3.00	1.70	1.00	1.40	.....	1.60
24	.....	.....	.....	3.20	4.60	5.60	2.90	1.60	1.00	1.40	.....	.....
25	.....	.....	.....	3.00	4.80	5.60	2.80	1.50	1.00	1.50	1.50	.....
26	.....	.....	.....	3.00	4.90	5.80	2.60	1.40	1.00	1.50	.....	.....
27	.....	.....	.....	3.10	4.80	6.00	2.60	1.40	0.90	1.60	.....	.....
28	.....	1.50	1.50	3.00	4.60	5.90	2.50	1.40	0.90	1.60	.....	.....
29	1.80	.....	.....	3.00	4.50	5.80	2.40	1.40	0.90	.....	.....	.....
30	.....	.....	.....	3.00	4.40	5.70	2.40	1.30	0.90	.....	.....	1.90
31	.....	.....	.....	.....	4.40	.....	2.30	1.30	.....	.....	.....	.....

NORTH PLATTE RIVER AT ORIN JUNCTION, WYOMING.

This river has its source in the mountains of North Park in northern Colorado. The general elevation of the park is 8,000 feet, and it is surrounded by mountains which attain an elevation of 12,000 feet. Irrigation is practiced to a considerable extent from small ditches, which are used almost entirely, however, in flooding native grass lands for forage purposes. The river passes through a short, narrow canyon on entering Wyoming, and thence flows northerly through the upper Platte Valley, which extends from the State line down to Fort Steel. The river thence continues northerly, receiving a number of important tributaries, notably Sweetwater River, in the basin of which considerable irrigation is practiced. The only station maintained in this State on this stream at present is at Orin Junction, at the bridge of the Cheyenne Northern Railway. The rod is attached to the mid-channel pier of the railroad bridge, and is connected with the following bench marks: The spike on top of the cap on the set of piles nearest the water at the east end of the bridge is 11.52 feet above gage datum. The bed of the stream is composed of heavy gravel and sand, the cross section being quite uniform. Measurements at this point are not altogether satisfactory, on account of the occurrence of bridge piers, which interfere with the uniform flow to a considerable extent. Results of measurements are found as follows: 1896, Eighteenth Annual Report, Part IV, page 153; 1897, Nineteenth Annual Report, Part IV, page 307; 1898, Twentieth Annual Report, Part IV,

page 266. The following discharge measurements were made during 1899 by A. J. Parshall:

April 24, gage height, 4.26 feet; discharge, 5,239 second-feet.
May 5, gage height, 3.70 feet; discharge, 4,115 second-feet.
May 19, gage height, 5.70 feet; discharge 13,422 second-feet.
June 12, gage height, 5.85 feet; discharge, 14,746 second-feet.
June 26, gage height, 6.85 feet; discharge, 20,855 second-feet.
July 12, gage height, 5.67 feet; discharge, 10,784 second-feet.
September 2, gage height, 1 foot; discharge, 239 second-feet.

Daily gage height, in feet, of North Platte River at Orin Junction, Wyoming, for 1899.

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	Ice.	.....	4.45	6.10	6.40	3.00	1.00	.....	1.60	.....
2	.....	.....	.....	4.25	5.95	.....	2.93	.98	1.00	.....	.....
3	.....	.....	.....	4.00	5.75	6.40	2.83	.....	1.00	.....	.....
4	4.55	3.00	.....	3.85	.....	6.30	2.73	.95	1.00	.....	.....
5	.....	.....	.....	3.70	6.15	6.20	2.55	.95	1.00	.....	.....
6	.....	.....	.....	3.65	6.20	6.15	.....	.95	.98	.....	.....
7	.....	.....	.....	.....	6.20	5.95	2.58	.95	.93	.....	.....
8	.....	.....	.....	3.35	6.15	5.75	2.75	.95	.....	1.40	Ice.
9	.....	.....	.....	3.45	5.95	.....	2.73	.95	1.00	.....	.....
10	.....	.....	2.65	3.85	5.75	5.35	2.70	.....	1.08	.....	.....
11	4.45	Ice.	2.85	4.15	.....	5.15	2.63	.90	1.25	.....	.....
12	.....	.....	3.95	4.30	5.95	4.98	2.45	.90	1.18	.....	.....
13	.....	.....	5.05	4.50	6.10	4.88	.....	.90	1.05	.....	.....
14	.....	.....	5.45	.....	6.50	4.83	2.08	.90	1.05	.....	.....
15	.....	.....	5.30	5.45	6.75	4.95	2.08	.95	.....	1.30	Ice.
16	.....	.....	.....	5.75	6.80	.....	1.98	1.60	1.20	.....	.....
17	.....	.....	5.05	5.85	6.80	4.75	1.88	.....	1.35	.....	.....
18	5.10	Ice.	4.80	5.95	.....	4.68	1.73	1.40	1.63	.....	.....
19	.....	.....	4.70	6.05	6.35	4.45	1.60	1.30	1.70	.....	.....
20	.....	.....	4.45	6.20	6.30	4.20	.....	1.65	1.70	.....	.....
21	.....	.....	4.10	.....	6.55	4.08	1.60	1.58	1.63	.....	.....
22	.....	.....	3.85	6.30	6.85	3.85	1.60	1.48	.....	1.30	Ice.
23	.....	.....	.....	6.20	6.95	.....	1.53	1.38	1.50	.....	.....
24	.....	.....	4.05	6.00	7.15	3.73	1.43	.....	1.50	.....	.....
25	.....	4.00	4.30	5.75	.....	3.63	1.33	1.23	1.58	.....	.....
26	.....	.....	4.90	5.55	6.85	3.60	1.23	1.20	1.73	.....	.....
27	.....	.....	5.70	5.35	6.65	3.45	.....	1.00	1.75	.....	.....
28	5.15	.....	5.70	.....	6.45	3.28	1.03	1.00	1.83	.....	.....
29	.....	.....	5.65	5.75	6.40	3.05	1.00	1.00	.....	1.25	Ice.
30	.....	.....	.....	6.05	6.40	.....	1.00	1.00	1.73	.....	Ice.
31	.....	.....	.....	6.10	.....	3.00	1.00	.....	1.60	.....	.....

NORTH PLATTE RIVER AT GERING, NEBRASKA.

This river does not receive any tributaries of importance after passing into Nebraska. A number of canals divert water between the State line and North Platte, at the junction of the North and South Platte rivers, and because of the nonincrease of the flow from important tributaries the water is constantly being reduced. A gaging station was established at Gering, Nebraska, May 29, 1897, and is located at the highway bridge at this point. The rod is fastened to one of the bridge piles. The bench mark is the head of a nail on top of the west end of the first cap at the south end of the bridge, and is 6.61 feet above gage datum. The results of discharge measurements are shown as follows: 1897, Nineteenth Annual Report, Part IV, page 308; 1898, Twentieth Annual Report, Part IV, page 267. The following discharge measurements were made by R. H. Willis during 1899:

Measurements of North Platte River at Gering, Nebraska.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Sec.-feet.*	1899.	*Feet.*	*Sec.-feet.*
Apr. 10	1.48	3,464	July 6	3.09	15,996
Apr. 21	2.10	9,776	July 11	2.75	12,806
May 2	2.35	11,096	July 18	2.38	11,232
May 16	2.10	8,575	July 26	1.90	6,198
May 26	2.90	12,942	Aug. 10	1.48	3,677
June 6	2.70	13,799	Aug. 18	1.40	2,658
June 14	2.90	14,176	Aug. 24	1.18	2,150
June 20	3.00	18,227	Sept. 21	1.05	860
June 26	3.55	23,473	Sept. 30	.95	957

Daily gage height, in feet, of North Platte River at Gering, Nebraska, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	.....	2.35	2.70	3.20	1.65	1.05	0.93
2	.....	2.37	2.71	3.15	1.70	1.02	.95
3	.....	2.35	2.66	3.10	1.75	1.00	.95
4	.....	2.10	2.61	3.07	1.70	1.02	.96
5	.....	2.00	2.60	3.10	1.58	1.04	.95
6	.....	1.95	2.72	3.05	1.55	1.01	.95
7	.....	1.90	3.10	3.00	1.51	1.01	.96
8	.....	1.75	3.00	2.95	1.47	1.00	.96
9	.....	1.73	2.83	2.87	1.48	1.00	.96
10	1.48	1.70	2.73	2.70	1.53	1.00	.97
11	1.41	1.68	2.69	2.75	1.47	1.00	1.06
12	1.53	1.64	2.68	2.68	1.50	1.00	1.07
13	1.85	1.82	2.80	2.55	1.48	1.00	1.07
14	2.22	1.93	2.90	2.46	1.37	.95	1.06
15	2.42	2.00	3.00	2.45	1.35	.95	1.07
16	2.51	2.25	3.20	2.44	1.43	1.00	1.04
17	2.58	2.40	3.25	2.42	1.40	.98	1.10
18	2.38	2.60	3.15	2.37	1.37	1.00	1.02
19	2.43	2.76	3.00	2.30	1.36	1.00	1.16
20	2.20	2.80	2.95	2.25	1.32	1.06	1.20
21	2.21	2.85	3.00	2.13	1.26	1.06	1.23
22	2.08	2.87	3.05	2.05	1.23	.98	1.25
23	1.92	2.87	3.20	2.00	1.23	1.03	1.27
24	1.90	3.10	3.27	2.00	1.20	1.03	1.23
25	1.88	2.85	3.50	1.95	1.20	.98	1.23
26	1.93	2.65	3.55	1.90	1.10	.98	1.23
27	2.12	2.43	3.50	1.85	1.10	1.00	1.27
28	2.40	2.41	3.30	1.81	1.10	.98	1.30
29	2.39	2.43	3.27	1.77	1.13	.91	1.30
30	2.37	2.52	3.25	1.67	1.10	.90	1.30
31	.....	2.70	.....	1.67	1.07	.....	1.30

Closed for winter October 31.

NORTH PLATTE RIVER AT CAMP CLARKE, NEBRASKA.

A third gaging station on this river is located at the bridge at Camp Clarke, Nebraska, and was established on June 27, 1896. The rod consists of an oak timber 2 by 4 inches, 10 feet long, fastened to cross-ties which are bedded in the bank of the river. Bench mark No. 1 consists of a spike driven horizontally in the northeast side of the downstream pile of the bent at the north end of the first truss span, on the south end of the bridge, and is 7.55 feet above gage datum. Bench mark No. 2 is a point on the southeast corner of the window sill at the front of the store, and is 9.74 feet above the zero of the gage. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 154; 1897, Nineteenth

Annual Report, Part IV, page 308; 1898, Twentieth Annual Report, Part IV, page 268. The following discharge measurements were made by R. H. Willis in 1899:

Measurements of North Platte River at Camp Clarke, Nebraska.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Sec.-feet.*	1899.	*Feet.*	*Sec.-feet.*
Apr. 11	2.57	2,823	July 20	3.97	9,855
Apr. 22	3.45	8,625	July 29	3.09	4,747
May 3	3.41	7,982	Aug. 5	2.90	4,187
May 17	3.52	9,646	Aug. 12	2.92	3,272
May 27	3.90	13,492	Aug. 19	2.67	2,359
June 8	4.42	15,607	Aug. 29	2.46	1,492
June 17	4.45	18,237	Sept. 5	2.13	965
June 24	5.05	18,330	Sept. 14	2.05	758
June 28	5.00	22,908	Sept. 23	2.08	794
July 8	4.76	18,705	Sept. 29	2.10	863
July 13	4.25	12,268	Oct. 19	2.15	1,110

Daily gage height, in feet, of North Platte River at Camp Clarke, Nebraska, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	.....	3.68	4.12	4.81	2.88	2.28	2.28
2	.....	3.73	4.18	4.83	2.98	2.22	2.27
3	.....	3.80	4.12	4.85	3.10	2.06	2.23
4	.....	3.13	4.10	4.88	3.03	2.03	2.32
5	2.55	3.34	4.09	4.80	2.88	2.11	2.21
6	2.60	3.30	4.22	4.87	2.88	2.16	2.19
7	2.62	2.80	4.40	4.83	2.90	2.00	2.30
8	2.67	2.80	4.35	4.82	2.84	2.10	2.20
9	2.68	2.74	4.25	4.70	2.75	2.12	2.28
10	2.58	2.80	4.21	4.50	2.85	2.16	2.25
11	2.55	2.73	4.02	4.45	2.95	2.11	2.28
12	2.54	2.87	3.97	4.40	2.91	2.02	2.22
13	2.86	2.99	4.02	4.25	3.08	2.03	2.29
14	3.26	3.02	4.06	4.14	2.81	2.15	2.23
15	3.76	3.19	4.22	4.20	2.74	2.13	2.34
16	3.70	3.40	4.45	(a)	2.84	2.15	2.25
17	3.58	3.61	4.48	(a)	2.82	2.17	2.30
18	3.58	3.74	4.25	(a)	2.77	2.18	2.25
19	3.60	3.87	4.10	4.00	2.70	2.21	2.22
20	3.65	4.06	(f)	3.93	2.68	2.23	2.25
21	3.50	4.19	(f)	3.80	2.60	2.21	2.40
22	3.43	4.32	4.80	3.75	2.62	2.19	.....
23	3.15	4.23	4.95	3.65	2.58	2.22	.....
24	3.08	4.19	5.08	3.50	2.55	2.40	.....
25	3.05	4.30	5.30	3.48	2.58	2.30	.....
26	3.05	4.03	5.35	3.32	2.48	2.23	.....
27	3.20	3.85	5.20	3.20	2.47	2.20	.....
28	3.55	3.75	5.00	3.20	2.48	2.30	.....
29	3.65	3.80	4.85	3.07	2.47	2.22	.....
30	3.75	3.92	4.85	2.93	2.35	2.25	.....
31	.....	4.03	.....	3.04	2.34	.....	.....

Discontinued October 31. a Bridge out. f Rod out.

NORTH PLATTE RIVER AT NORTH PLATTE, NEBRASKA.

The lowest gaging station on this river is located at the wagon bridge at North Platte, Nebraska, and was established in 1894. It is 3.5 miles above the junction of the South Platte River. The bridge is a long, low, pile bridge, having 93 spans of approximately 20 feet each, crossing the main channel of the river. North of this is another bridge crossing a slough, through which no water passes, however, except in time of flood. The gage rod is at the railroad bridge 2 miles

below the wagon bridge. The zero is 12 feet below the top and immediately under the east rail of the track. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 158; 1897, Nineteenth Annual Report, Part IV, page 309; 1898, Twentieth Annual Report, Part IV, page 269. The following discharge measurements were made by Glenn E. Smith and Charles P. Ross during 1899:

Measurements of North Platte River at North Platte, Nebraska.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Sec.-feet.*	1899.	*Feet.*	*Sec.-feet.*
Apr. 19	3.30	9,111	July 17	3.30	10,351
May 6	3.00	8,239	Aug. 8	2.50	4,637
May 22	3.80	12,962	Aug. 28	1.85	2,013
June 6	3.60	13,310	Sept. 15	1.55	976
June 15	3.60	11,330	Oct. 4	1.70	713
June 19	4.20	16,257			

Daily gage height, in feet, of North Platte River at North Platte, Nebraska, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.70	3.00	3.00	2.30	3.50	3.55	4.10	2.60	1.90	1.55	1.90	2.10
2	2.70	3.00	3.00	2.10	3.50	3.70	4.20	2.70	1.80	1.50	2.00	2.10
3	2.70	3.00	3.00	2.80	3.40	3.80	4.15	2.70	1.80	1.60	2.00	2.05
4	2.70	3.00	3.00	2.70	3.25	3.80	4.10	2.80	1.80	1.70	2.05	2.05
5	2.70	3.00	3.00	2.60	3.15	3.70	4.10	2.80	1.65	1.70	2.10	2.30
6	2.70	3.00	3.00	2.80	3.00	3.60	4.10	2.70	1.65	1.70	2.15	2.50
7	2.70	3.00	3.00	2.85	3.00	3.65	4.00	2.65	1.70	1.70	2.10	2.50
8	2.70	3.00	3.00	2.55	3.25	3.80	4.00	2.50	1.70	1.60	2.10	2.50
9	2.70	3.00	3.00	2.50	3.15	3.90	4.00	2.50	1.60	1.60	2.10	2.40
10	2.70	3.00	3.10	2.50	2.80	3.90	4.00	2.40	1.55	1.60	2.10	2.40
11	2.70	3.00	3.10	2.50	2.75	3.85	3.90	2.30	1.60	1.60	2.10	2.40
12	2.70	3.00	3.10	2.60	2.60	3.75	3.65	2.30	1.60	1.70	2.10	2.40
13	2.70	3.00	3.10	2.65	2.60	3.65	3.60	2.35	1.60	1.70	2.00	2.40
14	2.70	3.00	3.10	2.50	2.50	3.55	3.60	2.50	1.60	1.65	2.00	2.40
15	2.70	3.00	3.10	2.45	2.60	3.60	3.55	2.50	1.55	1.80	2.05	2.40
16	2.70	3.00	3.10	2.50	2.65	3.70	3.40	2.40	1.50	1.80	2.10	2.40
17	2.70	3.00	3.00	3.25	2 85	3.95	3.30	2.35	1.50	1.80	2.05	2.40
18	2.70	3.00	2.80	3.30	3.05	4.00	3.20	2.40	1.50	1.80	2.00	2.40
19	2.80	3.00	2.80	3.35	3.05	4.20	3.25	2.30	1.50	1.80	2.10	2.40
20	2.80	3.00	2.80	3.40	3.40	4.15	3.30	2.30	1.50	1.80	2.10	2.40
21	2.80	3.00	2.50	3.30	3.60	3.95	3.30	2.30	1.60	1.80	2.20	2.40
22	2.90	3.00	2.80	3.10	3.75	3.85	3.20	2.00	1.60	1.80	2.20	2.40
23	2.80	3.00	2.80	3.10	3.75	3.90	3.15	2.00	1.50	1.80	2.10	2.40
24	2.80	3.00	3.05	3.10	3.80	3.85	3.00	1.90	1.50	1.80	2.10	2.45
25	3.00	3.00	2.90	3.00	3.70	4.15	2.95	1.90	1.50	1.80	2.10	2.55
26	3.00	3.00	2.60	2.90	3.80	4.30	2.80	1.90	1.60	1.90	2.10	2.70
27	3.00	3.00	2.60	3.00	3.85	4.45	2.80	1.90	1.60	2.00	2.10	2.70
28	3.00	3.00	2.55	3.00	3.85	4.40	2.85	1.85	1.55	2.00	2.20	2.70
29	3.00	.....	2.50	3.00	3.75	4.30	2.70	1.75	1.60	2.00	2.10	2.70
30	3.00	.....	2.55	3.10	3.50	4.25	2.70	1.65	1.60	2.00	2.10	2.70
31	3.00	.....	2.60	.....	3.50	.....	2.55	1.75	.....	1.95	.....	2.65

SOUTH PLATTE RIVER.

The headwater tributaries of this stream have their sources in the high mountain peaks surrounding the basin known as South Park. The average elevation of the valley is 8,000 feet, while the peaks attain an elevation of 13,000 feet. Considerable irrigation is practiced on a small scale, but principally for forage crops, as on account of the high altitude only the hardier products can be raised. The

streams have a general northerly direction, and upon issuing from the mountainous area the water is quickly appropriated by the large irrigation enterprises serving land on both sides of the South Platte River in the vicinity of Denver. A number of smaller streams rising on the eastern slope of the Rocky Mountains drain easterly into the South Platte River. The principal tributaries are—in order downstream—Bear Creek, Clear Creek, South Boulder Creek, Boulder Creek, St. Vrain Creek, Big Thompson Creek, and Cache la Poudre River. Gaging stations have been maintained on them also as well as one at Lake Cheesman on the South Fork of South Platte, and one on Goose Creek, which also contributes to the supply of the proposed reservoir. The next one downstream on the main river is at Platte Canyon, the third one at Denver, and the lower one at Orchard, Colorado. Besides the measurements of discharge at regular stations a number of others have been made in this basin during 1899, as follows: April 14 a measurement of the High-line ditch in the South Platte, at a gage height of 1.20 feet, showed a discharge of 98 second-feet. On July 28 the same canal was measured twice, the first time at a gage height of 3.25 feet, showing a discharge of 432 second-feet; the second time at a gage height of 3 feet, with a discharge of 375 second-feet. On the same day also the South Platte River was discharging over the High-line dam, at a gage height of 0.50 foot, 73 second-feet. September 14, South Platte River, at Julesburg, was carrying 2 second-feet. October 4 the river at the dam of the High-line canal, at a gage height of 0.13 foot, was discharging 12 second-feet.

A notable storage proposition on which work was prosecuted during the past season is that of the dam of Lake Cheesman, which is located on the South Fork of South Platte River, below the mouth of Goose Creek. The dam, which is partially completed, will be 215 feet high. Its length at its base is only 20 feet and at the top it will be 520 feet. The abutments are solid granite. The main tunnel for diverting the flow during the course of the construction of the dam is now completed, and work is now progressing on two subsidiary tunnels. The dam is to be rock filled and steel plate faced. The capacity of the reservoir is about 90,000 acre-feet. The object of this enterprise is to develop electric power to be used in the city of Denver, and also to furnish a water supply for the same city.

GOOSE CREEK AT LAKE CHEESMAN, COLORADO.

The station on this creek, a tributary of South Platte River, was established August 1, 1899, by J. A. Runner, assistant engineer of the Denver Union Water Company. It was desired to obtain the flow of the South Fork of South Platte River at this point, where the construction of the Cheesman dam has been begun, the discharge of Goose Creek being added to the South Fork of South Platte to give

the total flow at this point. The station is maintained by the Denver Union Water Company. All discharge measurements for 1899 have been made by means of floats. This station is to be considered simply as temporary, as it will be necessary to move it farther upstream when water is stored in the reservoir. The following discharge measurements were made by J. A. Runner during 1899:

September 8, gage height, 0.95 foot; discharge, 24 second-feet.
October 8, gage height, 0.84 foot; discharge, 10 second-feet.
November 19, gage height, 0.72 foot; discharge, 8 second-feet.
December 3, gage height, 0.76 foot; discharge, 9 second-feet.

Daily gage height, in feet, of Goose Creek at Lake Cheesman, Colorado, for 1899.

Day.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.25	0.97	0.85	.....	0.80	17	1.04	.90	.86	.....	.....
2	1.20	.95	.85	.....	.....	18	1.00	.89	.86	.85	.74
3	1.30	a.95	.85	.....	.76	19	.98	.88	.87	.....	.....
4	1.32	a.95	.85	0.85	.....	20	.96	.88	.87	.....	.80
5	1.35	a.95	.86	.....	.74	21	.96	.88	.88	.84	.....
6	1.15	a.95	.85	.86	.....	22	.95	.88	.88	.....	.....
7	1.25	a.95	.85	.....	.....	23	.94	a.88	.88	.....	.....
8	1.25	.95	.84	.87	.....	24	.93	a.88	.....	.83	.....
9	1.10	.94	.84	.87	.....	25	.93	a.88	.....	.....	.....
10	1.09	.94	.85	.....	.72	26	.92	.87	.....	.80	.....
11	1.06	.92	.85	.87	.....	27	.91	.87	.....	.....	.....
12	1.05	.90	.85	.....	.73	28	.90	.86	.....	.....	.....
13	1.05	.89	.85	.....	.....	29	.91	.86	.....	.80	.....
14	1.05	.88	.85	.86	.74	30	.93	.85	.....	.....	.....
15	1.04	.89	.85	.....	.....	31	.96	.....	.....	.....	.....
16	1.04	.90	.85	.85	.73						

a Estimated.

SOUTH FORK OF SOUTH PLATTE RIVER AT LAKE CHEESMAN, COLORADO.

This station was established July 31, 1899, and has been maintained since that time by the Denver Union Water Company, J. A. Runner, assistant engineer, making the discharge measurements. It is located above the mouth of Goose Creek, and is maintained in order to determine the flow available for Lake Cheesman. The discharge here should be added to the discharge of Goose Creek, as the dam for this reservoir is located below the mouth of the latter tributary. It will be necessary in this case, as in the preceding one, to move the station upstream when water has been stored in the reservoir, so the station can be considered merely as a temporary one. It is the intention that both the inflow and the discharge from the reservoir shall be accurately measured after the storage has begun. The following measurements of discharge were made by J. A. Runner by means of floats in 1899:

July 31, gage height, 3.62 feet; discharge, 806 second-feet.
September 8, gage height, 1.45 feet; discharge, 184 second-feet.
October 8, gage height, 1.23 feet; discharge, 95 second-feet.
November 19, gage height, 1.30 feet; discharge, 107 second-feet.
December 3, gage height, 1.24 feet; discharge, 97 second-feet.

Daily gage height, in feet, of South Platte River at Lake Cheesman, Colorado, for 1899.

Day.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.55	1.51	1.23	.....	1.26	17	1.72	1.34	1.30	.....	.....
2	2.20	1.50	1.23	.....	.....	18	1.72	1.36	1.20	1.28	1.02
3	2.60	(a)	1.23	.....	1.24	19	1.67	1.37	1.20	1.30	.....
4	3.70	(a)	1.24	1.20	.....	20	1.60	1.36	1.28	.....	1.10
5	3.55	(a)	1.26	.....	1.14	21	1.57	1.37	1.30	.....	.....
6	3.10	(a)	1.05	1.43	.....	22	1.56	1.38	1.28	1.24	.....
7	2.50	(a)	.88	.....	.....	23	1.54	(a)	1.27	.....	1.20
8	2.60	1.45	.86	1.45	.....	24	1.53	(a)	.....	1.29	.....
9	2.35	1.45	.85	1.41	.....	25	1.50	(a)	.....	.....	.....
10	2.15	1.44	.80	.....	.92	26	1.50	(a)	.....	.98	.....
11	1.98	1.42	.80	1.41	.....	27	1.48	1.28	.....	.....	.....
12	1.96	1.40	.80	.....	.90	28	1.46	1.27	.....	.....	.....
13	1.92	1.38	.90	.....	.....	29	1.44	1.26	.....	1.30	.....
14	1.87	1.33	1.10	1.40	.92	30	1.43	1.23	.....	.....	.....
15	1.79	1.32	1.40	.....	.....	31	1.48	.....	.....	.....	.....
16	1.70	1.33	1.40	1.20	1.00						

a No readings.

SOUTH PLATTE RIVER AT PLATTE CANYON, COLORADO.

This station has been maintained for sometime by the Denver Union Water Company, but cooperation with this Survey was not begun until April 1, 1899. The station is located at a point about 2 miles above Platte Canyon railway station, on the Colorado and Southern Railroad. The rod is an inclined 2 by 6 timber on the right-hand side of the stream, marked with brass nails. The bench mark is a point chiseled in a circle just south of the Denver Union Water Company's pipe line, and 15 feet south of the zero point of soundings on the bridge. It is on a granite rock and is 10 feet above gage datum. Measurements of discharge are made from the footbridge constructed by the Denver Union Water Company. The channel of the stream is rocky, and at first it was considered that it was not liable to material change; but during a freshet of considerable size erosion took place, making necessary a change in the rating table. This station gives the total discharge of the river at Platte Canyon before any water is taken out for irrigation or any other purposes excepting that taken out by the Denver Union Water Company at a point about 1 mile above the station. The observer, G. E. Carleton, Littleton, Colorado, is superintendent of the filtering plant belonging to the Denver Union Water Company. He furnishes gage readings to the United States Weather Bureau at Denver, where they are published each day. The following discharge measurements were made under the direction of A. L. Fellows during 1899:

April 14, 1899, gage height, 1.8 feet; discharge, 559 second-feet.
May 8, 1899, gage height, 1.5 feet; discharge, 500 second-feet.
June 10, 1899, gage height, 2.9 feet; discharge, 1,127 second-feet.
July 28, 1899, gage height, 1.8 feet; discharge, 633 second-feet.
October 4, 1899, gage height, 0.1 feet; discharge, 146 second-feet.

Daily gage height, in feet, of South Platte River at Platte Canyon, Colorado, for 1899.

Day.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.50	1.40	2.50	3.20	2.50	0.90	0.10	0.40	—0.10
2	.50	1.50	2.50	3.80	2.20	.90	.00	.30	— .40
3	.55	1.50	2.50	4.10	2.60	.90	.00	.40	— .40
4	.60	1.20	2.60	4.10	3.30	.80	.00	.40	—1.10
5	.60	1.10	2.40	3.90	3.30	.70	.10	.40	—1.90
6	.50	1.10	2.40	3.60	2.90	.60	.10	.40	— .60
7	.60	1.20	2.50	3.40	2.70	.60	.10	.30	— .60
8	.60	1.50	2.80	3.40	2.50	.60	—.20	.40	— .70
9	.70	1.90	3.00	3.30	2.30	.60	—.30	.40	— .80
10	.70	2.10	2.90	3.10	2.00	.60	—.30	.30	— .40
11	.80	2.20	3.00	2.80	1.90	.60	—.20	.30	— .20
12	1.20	2.30	3.20	2.70	1.60	.50	—.20	.30	.10
13	1.50	2.50	3.30	2.70	1.60	.50	—.10	.30	.30
14	1.80	2.60	3.50	3.00	1.60	.50	—.10	.30	.00
15	1.90	2.60	3.40	3.00	1.50	.50	.20	.20	.30
16	1.70	2.70	3.50	3.00	1.40	.50	.20	.30	.60
17	1.80	2.60	3.50	3.20	1.40	.50	.30	.10	.70
18	2.00	2.60	3.50	3.30	1.30	.50	.40	.10	.50
19	1.80	2.50	3.50	3.10	1.20	.50	.40	.00	.50
20	1.70	2.50	4.65	3.00	1.10	.50	.30	—.20	.50
21	1.40	2.40	4.20	2.60	1.00	.40	.30	.10	.60
22	1.40	2.30	4.20	2.40	1.00	—.10	.30	.00	.60
23	1.50	2.30	3.90	2.20	.90	+.20	.20	.20	.60
24	1.60	2.40	3.60	2.10	.80	.50	.20	.20	.60
25	1.80	2.40	3.60	2.00	.80	.20	.30	—.20	.50
26	2.10	2.50	3.70	1.90	.70	.30	.30	—.40	.40
27	1.90	2.50	3.60	1.90	.70	.20	.30	—.60	.20
28	1.90	2.50	3.40	1.80	.70	.20	.30	—.30	.30
29	1.70	2.50	3.30	2.20	.70	.10	.30	.10	.30
30	1.60	2.50	3.20	2.80	.70	.10	.30	—.10	.30
31	.....	2.50	.....	3.10	1.10	.....	.30	.....	.40

SOUTH PLATTE RIVER AT DENVER, COLORADO.

The gaging station at this point, established July 15, 1895, is located at the Fifteenth street bridge in the city of Denver, immediately below the mouth of Cherry Creek. The rod at present used is fastened to a post in the left bank of the river and graduated to vertical feet and tenths. The bench mark is a cross on top of east abutment of the Fifteenth street bridge on the north corner, and is 15.15 feet above gage datum. The river is confined between slag embankments, and the bed, although sandy and shifting, did not materially change during 1899. Mr. W. J. Southland, water commissioner of Colorado Irrigation District No. 2, cooperated with this survey in furnishing the gage readings, which are also transmitted to the United States Weather Bureau, and published each day in the Denver daily papers. The station is an important one, and it is fortunate that it can so easily be reached and discharge measurements made without great expense. Results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 165; 1897, Nineteenth Annual Report, Part IV, page 313; 1898, Twentieth Annual Report, Part IV, page 279. The following measurements of discharge were made by A. L. Fellows in 1899:

April 12, gage height, 6.0 feet; discharge, 422 second-feet.
May 11, gage height, 6.03 feet; discharge, 355 second-feet.
June 12, gage height, 6.2 feet; discharge, 764 second-feet.
July 27, gage height, 5.32 feet; discharge, 213 second-feet.
August 4, gage height, 6.93 feet; discharge, 1,200 second-feet.
September 6, gage height, 5.95 feet: discharge, 288 second-feet.
October 5, gage height, 5.1 feet; discharge, 100 second-feet.

Daily gage height, in feet, of South Platte River at Denver, Colorado, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.80	4.80	6.10	6.10	5.85	5.90	6.30	6.20	6.00	5.20	5.15	5.55
2	4.70	4.80	6.00	6.05	5.85	5.90	6.65	5.95	5.95	5.20	5.25	5.65
3	4.80	4.80	6.00	6.00	5.75	6.10	6.95	5.90	6.00	5.15	5.35	5.15
4	4.90	4.80	5.90	5.95	5.75	5.90	7.10	7.00	6.00	5.10	5.40	5.25
5	4.90	4.90	5.90	5.90	5.80	6.00	7.00	7.20	5.90	5.10	5.30	5.35
6	4.80	4.90	5.80	5.80	5.95	5.95	6.60	6.95	5.85	5.10	5.25	5.50
7	4.90	4.80	5.80	5.75	5.85	6.30	6.45	6.75	5.90	5.05	5.35	5.50
8	4.90	4.70	5.70	5.80	5.75	6.50	6.40	6.60	5.80	4.90	5.40	5.15
9	4.80	4.80	5.60	5.90	5.75	6.50	6.40	6.45	5.80	4.90	5.25	5.15
10	4.70	4.90	5.50	6.05	6.05	6.45	6.35	6.30	5.80	5.00	5.20	5.30
11	4.80	4.80	5.60	6.15	6.05	6.25	6.15	6.20	5.75	5.00	5.40	5.05
12	4.80	4.90	5.70	6.10	6.10	6.25	6.00	6.20	5.75	5.00	5.70	5.15
13	4.90	5.10	5.60	6.15	6.25	6.45	5.95	6.00	5.70	5.10	5.60	5.15
14	5.00	5.20	5.80	6.20	6.25	6.50	6.40	6.00	5.65	5.20	5.50	5.05
15	4.90	5.30	5.80	6.25	6.35	6.65	6.25	6.00	5.70	5.20	5.55	5.20
16	4.90	5.30	5.90	6.30	6.30	6.60	6.30	5.90	5.75	5.25	5.45	5.30
17	4.80	5.40	6.00	6.20	6.25	6.65	6.40	5.65	5.80	5.15	5.55	5.25
18	4.90	5.70	6.10	6.35	6.20	6.65	6.45	5.65	5.75	5.05	5.35	5.30
19	4.80	6.30	6.15	6.25	6.08	6.65	6.60	5.55	5.75	5.15	5.45	5.35
20	4.80	6.20	6.25	6.05	6.08	6.85	6.30	5.65	5.80	5.20	5.70	5.25
21	4.80	6.00	6.30	5.95	6.00	7.10	6.20	6.05	5.70	5.10	5.65	5.25
22	4.70	5.90	6.20	5.95	5.90	7.00	6.00	6.02	5.65	5.15	5.75	5.25
23	4.80	5.70	6.05	5.95	5.80	6.90	5.90	5.98	5.60	5.25	5.70	5.30
24	4.70	5.60	6.00	6.00	5.88	6.90	5.80	5.92	5.30	5.30	5.70	5.35
25	4.80	5.50	5.90	5.95	5.80	6.80	5.70	5.85	5.60	5.20	5.60	5.40
26	4.90	5.60	5.95	6.10	5.85	6.70	5.60	5.75	5.60	5.20	5.65	5.40
27	4.80	5.80	6.05	6.15	5.88	6.65	5.50	5.65	5.60	5.30	5.65	5.25
28	4.70	6.20	6.10	6.05	5.95	6.55	5.30	5.75	5.65	5.25	5.70	5.30
29	4.80	.....	6.20	5.95	6.30	6.40	5.20	5.80	5.50	5.15	5.60	5.40
30	4.80	.....	6.15	5.90	5.95	6.30	5.90	5.90	5.20	5.25	5.50	5.30
31	4.80	.....	6.10	.....	5.85	.....	6.10	6.00	.....	5.15	.....	5.40

SOUTH PLATTE RIVER AT ORCHARD, COLORADO.

This station, on the lower South Platte River, is located one-fourth of a mile southwest of Orchard, Colorado. The gage is vertical and is fastened to a pile of the wagon bridge. The gage rod is not referred to any satisfactory bench mark, and consequently when the pile to which the rod was nailed was raised a number of tenths by ice about March 17, it was necessary that a new rating table be made for observations after that date. The left bank is high and the right low and liable to overflow. The bed of the stream is sandy and shifting, although the section did not materially change during 1899. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 166; 1897, Nineteenth Annual Report, Part IV, page 315; 1898, Twentieth Annual Report, Part IV, page 293. The following measurements of discharge were made under the direction of A. L. Fellows in 1899:

April 14, gage height, 3.2 feet; discharge, 1,258 second-feet.
May 27, gage height, 2.3 feet; discharge, 158 second-feet.
September 12, gage height, 2.05 feet; discharge, 57 second-feet.
November 3, gage height, 2.80 feet; discharge, 614 second-feet.

Daily gage height, in feet, of South Platte River at Orchard, Colorado, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.50	4.40	5.00	3.20	3.20	2.10	3.40	2.80	2.00	2.30	2.80	3.00
2	4.50	4.40	5.00	3.20	3.20	2.10	3.45	2.75	2.00	2.30	2.80	3.00
3	4.50	4.40	5.00	3.20	3.10	2.10	3.70	2.70	1.90	2.30	2.80	3.00
4	4.50	4.40	5.00	3.20	3.10	2.10	3.90	2.70	1.90	2.30	2.80	3.00
5	4.50	4.40	5.00	3.20	3.10	2.00	4.20	2.90	1.90	2.30	2.80	3.00
6	4.50	4.40	5.00	3.20	3.00	2.00	4.00	4.20	1.90	2.30	2.80	3.00
7	4.50	4.40	4.90	3.20	3.00	2.00	3.80	4.20	1.90	2.30	2.80	3.00
8	4.40	4.40	4.80	3.20	3.00	2.00	3.90	4.00	1.90	2.30	2.80	3.00
9	4.40	4.40	4.50	3.20	3.00	1.90	4.20	3.80	1.90	2.30	2.85	3.00
10	4.40	4.40	4.50	3.20	2.80	1.90	4.00	3.70	1.90	2.35	2.85	3.00
11	4.40	4.40	4.50	3.20	2.80	1.90	3.50	3.40	1.90	2.40	2.90	3.00
12	4.40	4.40	4.50	3.20	2.80	1.85	3.20	3.20	1.90	2.50	2.90	3.00
13	4.40	4.45	4.50	3.20	2.50	1.90	3.00	3.20	1.90	2.60	2.90	3.20
14	4.40	4.50	4.50	3.20	2.50	3.00	3.10	3.20	1.90	2.70	2.90	3.20
15	4.40	4.60	4.00	3.20	2.50	3.20	3.20	2.70	1.90	2.80	2.90	3.20
16	4.40	4.70	4.00	3.20	2.50	3.20	3.50	2.65	1.90	2.80	2.90	3.20
17	4.40	4.75	4.00	3.20	2.50	3.20	3.80	2.60	1.90	2.80	2.95	3.20
18	4.40	4.80	3.50	3.25	2.30	3.20	3.90	2.50	1.90	2.80	2.98	3.20
19	4.40	4.80	3.20	3.30	2.30	3.20	4.00	2.40	1.90	2.80	3.00	3.30
20	4.40	5.00	3.20	3.30	2.20	3.20	3.70	2.40	1.95	2.80	3.00	3.40
21	4.40	5.00	3.20	3.30	2.20	3.90	3.60	2.35	1.95	2.80	3.00	3.60
22	4.40	5.00	3.20	3.30	2.20	4.40	3.30	2.30	2.00	2.80	3.00	3.70
23	4.40	5.00	3.20	3.30	2.20	4.50	3.20	2.30	2.00	2.80	3.00	3.80
24	4.40	5.00	3.20	3.30	2.20	4.60	3.00	2.20	2.10	2.80	3.00	3.90
25	4.40	5.00	3.20	3.30	2.20	4.20	2.90	2.15	2.10	2.80	3.00	3.90
26	4.40	5.00	3.20	3.30	2.20	4.10	2.85	2.10	2.20	2.80	3.00	3.90
27	4.40	5.00	3.20	3.30	2.20	4.00	2.70	2.00	2.20	2.80	3.00	4.00
28	4.40	5.00	3.20	3.30	2.20	3.90	2.60	2.00	2.20	2.80	3.00	4.00
29	4.40	.....	3.20	3.30	2.20	3.70	2.60	2.00	2.30	2.80	3.00	4.00
30	4.40	.....	3.20	3.30	2.20	3.60	2.50	2.00	2.30	2.80	3.00	4.00
31	4.40	.....	3.20	.....	2.20	.....	2.80	2.00	.....	2.80	.....	4.00

The water diversions from this stream in Colorado are so extensive that during the summer season a comparatively insignificant flow reaches Nebraska. Measurements of the South Platte were made near its junction with the North Platte. On April 19, 1899, Glenn E. Smith made a measurement from the wagon bridge south of the town of North Platte, and found the total width to be 1,296 feet, while the discharge was 883 second-feet; on May 6 the discharge was 866 second-feet, and on May 22, 88 second-feet. At this time the water was flowing in a number of small channels scattered across the sandy bed. On June 6 the channel was dry.

BEAR CREEK AT MORRISON, COLORADO.

This stream, a tributary of the South Platte, drains a portion of the eastern slope of the Rocky Mountains and enters the main stream 8 miles above Denver. The station is located in the upper part of the town of Morrison. The present station was established April 16, 1899, by John E. Field, State engineer, and is located about a quarter of a mile above the railway station. The gage rod consists of a 2 by 4 timber placed vertically and marked in feet and tenths, and is fastened to the upper side of the dam which diverts water into the mains of the Denver Union Water Company. At the height of 4 feet on the gage rod water begins to flow over the spillway, making a marked difference in the rating curve. The bench mark consists of the top of a granite bowlder about 100 feet above the rod and on the left-hand side of the stream, and is 10.33 feet above gage datum. The station was maintained during the year through cooperation with the Denver Union Water Company. Previous results of measurements may be

found as follows: 1896, Eighteenth Annual Report, Part IV, page 167; 1897, Nineteenth Annual Report, Part IV, page 317; 1898, Twentieth Annual Report, Part IV, page 284. The following discharge measurements were made under the direction of A. L. Fellows during 1899:

April 15, gage height, 3.80 feet; discharge, 64 second-feet.
May 9, gage height, 4.25 feet; discharge, 99 second-feet.
June 16, gage height, 4.25 feet; discharge, 107 second-feet.
August 5, gage height, 4.98 feet; discharge, 192 second-feet.
November 14, gage height, 1.35 feet; discharge, 13 second-feet.

Daily gage height, in feet, of Bear Creek at Morrison, Colorado, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	.....	4.05	4.05	4.15	4.10	3.35	2.00
2	.....	4.10	4.05	4.40	4.15	3.35	1.90
3	.....	3.20	3.95	4.45	5.25	3.25	1.90
4	.....	3.25	3.85	4.45	5.80	3.25	1.90
5	.....	3.55	3.55	4.20	5.20	3.15	1.80
6	.....	3.65	3.90	4.05	5.05	2.95	1.80
7	.....	3.90	4.20	4.20	4.90	2.80	1.80
8	.....	4.15	4.15	4.20	4.75	2.65	1.80
9	.....	4.20	4.30	4.05	4.65	2.65	1.80
10	.....	4.20	4.15	3.75	4.65	2.55	2.20
11	.....	4.40	4.15	3.65	4.55	2.70	2.10
12	.....	4.55	4.20	3.65	4.55	2.75	2.10
13	.....	4.60	4.30	4.10	4.45	2.70	2.00
14	.....	4.70	4.25	4.25	4.35	2.65	2.00
15	.....	4.70	4.15	4.30	4.25	2.60	2.05
16	4.20	4.65	4.15	4.30	4.15	2.70	2.00
17	4.20	4.60	4.15	4.50	4.20	2.75	1.95
18	4.15	4.50	4.15	4.10	3.95	2.65	1.90
19	4.15	4.45	4.25	4.00	3.75	2.60	1.80
20	3.95	4.45	4.30	4.00	3.65	2.45	1.80
21	3.75	4.25	4.25	3.95	3.45	2.45	1.70
22	4.00	4.25	4.25	3.90	3.35	2.35	.....
23	4.05	4.25	4.15	3.85	3.25	2.25	.....
24	4.20	4.25	4.15	3.75	3.15	2.20	.....
25	4.20	4.25	4.30	3.65	3.05	2.20	.....
26	4.10	4.25	4.15	3.75	3.05	2.15	.....
27	4.10	4.25	4.15	3.75	2.95	2.10	.....
28	4.00	4.25	4.05	3.75	2.75	2.10	.....
29	3.85	4.15	4.05	4.25	2.55	2.05	.....
30	3.65	4.15	4.20	4.15	2.45	2.00	.....
31	.....	4.15	.....	3.90	3.35	.....	.....

Closed for the winter October 21.

CLEAR CREEK AT FORKSCREEK, COLORADO.

This stream rises on the eastern slope of the Rocky Mountains almost due west of Denver, and flows in an easterly direction, entering the South Platte River 6 miles below the center of the city of Denver. The small summer flow of this stream is completely utilized for irrigation purposes. The gaging station, established by John E. Field, State engineer, March 29, 1899, is located at the railway station at Forkscreek, on the Colorado and Southern Railway, in Clear Creek Canyon, just below the junction of the North and South forks. The gage consists of a weight fastened to a wire running over a pulley fastened to a rock at the railway station. Bench mark No. 1 is a point on the timber to which the pulley is attached, and is 13.58 feet above gage datum. Bench mark No. 2 is a granite point 49.5 feet east of the first bench mark, and is 15.46 feet above gage datum. The channel is rocky and not liable to serious change. The walls are high and not liable to overflow. On April 20 measurements of the North and

South forks were made separately and gave 43 second-feet and 101 second-feet, respectively. The following discharge measurements were made under the direction of A. L. Fellows during 1899:

March 29, gage height, 1.50 feet; discharge, 52 second-feet.
April 20, gage height, 2.10 feet; discharge, 155 second-feet.
May 10, gage height, 2.75 feet; discharge, 365 second-feet.
June 7, gage height, 3.70 feet; discharge, 779 second-feet.
August 12, gage height, 3.08 feet; discharge, 449 second-feet.
November 15, gage height, 1.70 feet; discharge, 67 second-feet.

Daily gage height, in feet, of Clear Creek at Forkscreek, Colorado, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.65	2.55	(a)	4.45	3.35	2.60	2.10	2.10	1.40
2	1.75	2.50	(a)	4.40	3.30	2.75	2.10	2.05	1.40
3	1.65	2.50	(a)	4.30	3.35	2.60	2.10	2.00	.....
4	1.65	2.25	(a)	4.05	3.40	2.60	2.00	2.00	.....
5	1.70	2.35	(a)	4.00	3.55	2.60	2.00	1.90	.....
6	1.55	2.40	(a)	4.05	3.35	2.50	2.00	1.85	.....
7	1.75	2.45	3.70	4.00	3.30	2.40	2.00	1.75	.....
8	1.70	2.45	3.75	4.00	3.30	2.40	2.00	1.75	.....
9	1.85	2.60	3.80	3.95	3.25	2.30	2.00	1.80	.....
10	1.95	2.85	3.80	3.90	3.15	2.30	2.00	1.80	.....
11	2.20	3.10	3.90	3.75	3.10	2.30	2.00	1.80	.....
12	2.20	3.50	4.15	3.70	3.05	2.30	2.00	1.80	.....
13	2.05	3.75	4.30	3.70	3.00	2.30	2.10	1.80	.....
14	2.15	4.00	4.40	3.70	3.00	2.30	2.05	1.80	.....
15	2.20	4.10	4.20	3.70	3.00	2.30	2.10	1.70	.....
16	2.30	4.25	4.25	3.70	3.00	2.30	2.10	1 70	.....
17	2.30	4.20	4.30	3.70	2.95	2.30	2.10	1.70	.....
18	2.30	4.35	4.45	3.60	2.90	2.30	2.10	1.65	.....
19	2.15	4.45	4.65	3.50	2.85	2.20	2.10	1.60	.....
20	2.10	(a)	4.70	3.50	2.80	2.20	2.00	1.55	.....
21	2.20	(a)	4.75	3.50	2.75	2.20	2.00	1.50	.....
22	2.20	(a)	4.70	3.50	2.70	2.20	2.00	1.55	.....
23	2.45	(a)	4.40	3.50	2.70	2.20	2.00	1.65	.....
24	2.50	(a)	4.40	3.40	2.70	2.20	2.00	1.50	.....
25	2.75	(a)	4.25	3.40	2.70	2.20	2.00	1.40	.....
26	2.90	(a)	4.25	3.40	2.70	2.20	2.05	1.40	.....
27	2.80	(a)	4.15	3.40	2.70	2.20	2.10	1.40	.....
28	2.80	(a)	4.10	3.40	2.60	2.10	2.00	1.40	.....
29	2.30	(a)	4.10	3.45	2.60	2.10	2.00	1.40	.....
30	2.45	(a)	4.25	3.40	2.60	2.10	2.00	1.40	.....
31	.....	(a)	.....	3.40	2.60	.....	2.05	.....	.....

a Gage broken; no reading.

SOUTH BOULDER CREEK AT MARSHALL, COLORADO.

This stream, the next one of importance entering below Clear Creek, is measured at a point about 3 miles west of Marshall, Colorado. The gage is an inclined 2 by 6 inch timber fastened to a tree and stakes driven into the ground. The bench mark is a stone 15 feet west of the gage, marked with black paint, and is 6.99 feet above gage datum. The gage was verified August 10, 1899. Two ditches divert water at points above the station, viz, the South Boulder and Coal Creek ditch and the Community ditch, and their discharge must be added to the discharge as found at the station to determine the total run-off of the basin. May 6 South Boulder and Coal Creek ditch, at a gage height of 0.7 foot, was discharging 7 second-feet, and on the same date Community ditch, at a gage height of 2.25 feet, was carrying 35 second-feet. C. E. Barber, Langford, Colorado, is the observer. Measurements are usually made by wading, but a footbridge near by can be used in high water. Results of measurements may be found as fol-

lows: 1896, Eighteenth Annual Report, Part IV, page 169; 1897, Nineteenth Annual Report, Part IV, page 318; 1898, Twentieth Annual Report, Part IV, page 287. The following discharge measurements were made under the direction of A. L. Fellows in 1899:

April 22, gage height, 1.70 feet; discharge, 115 second-feet.
May 6, gage height, 1.55 feet; discharge, 96 second-feet.
June 15, gage height, 2.80 feet; discharge, 451 second-feet.
August 10, gage height, 1.60 feet; discharge, 109 second-feet.
October 10, gage height, 0.70 foot; discharge, 7 second-feet.

Daily gage height, in feet, of South Boulder Creek at Marshall, Colorado, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Day.	Apr.	May.	June.	July.	Aug.	Sept.
1	0.90	1.80	2.50	2.65	1.65	1.30	17	1.75	2.65	2.85	2.15	1.40	1.10
2	1.00	1.80	2.55	2.65	1.55	1.30	18	1.75	2.60	2.90	2.10	1.40	1.10
3	.95	1.65	2.50	2.55	1.65	1.30	19	1.80	2.65	2.95	2.10	1.40	1.10
4	1.00	1.65	2.35	2.45	1.85	1.25	20	1.80	2.65	3.00	2.00	1.35	1.00
5	.95	1.60	2.30	2.45	2.00	1.20	21	1.80	2.50	3.00	2.05	1.30	1.05
6	1.00	1.60	2.35	2.40	1.90	1.20	22	1.85	2.45	3.00	2.00	1.30	.90
7	.95	1.65	2.45	2.35	1.80	1.20	23	1.80	2.35	2.85	2.00	1.35	.90
8	1.00	1.70	2.55	2.30	1.85	1.20	24	1.95	2.30	2.80	1.95	1.30	.90
9	1.05	1.90	2.60	2.25	1.70	1.20	25	2.10	2.40	2.70	1.90	1.30	.90
10	1.15	2.25	2.70	2.30	1.60	1.10	26	2.15	2.55	2.65	1.85	1.30	.90
11	1.25	2.25	2.65	2.30	1.60	1.00	27	2.25	2.60	2.65	1.85	1.30	.90
12	1.40	2.35	2.80	2.25	1.60	1.00	28	2.20	2.55	2.55	1.80	1.25	.90
13	1.60	2.35	2.90	2.50	1.50	1.00	29	2.15	2.50	2.55	1.70	1.20	.90
14	1.65	2.55	2.95	2.35	1.50	1.00	30	1.90	2.55	2.60	1.60	1.30	.90
15	1.75	2.60	2.90	2.45	1.40	1.00	31	.....	2.55	.....	1.55	1.30	.....
16	1.80	2.70	2.85	2.25	1.50	1.05							

Closed for the winter September 30.

Daily gage height, in feet, of South Boulder and Coal Creek ditch, Colorado, for 1899.

Day.	May.	June.	July.	Aug.	Day.	May.	June.	July.	Aug.	Day.	May.	June.	July.	Aug.
1	.....	1.35	1.50	1.20	12	.....	1.50	1.30	1.00	23	1.10	1.50	1.20	.....
2	.....	1.30	1.50	1.20	13	.....	1.50	1.30	1.00	24	1.10	1.50	1.20	.....
3	.....	1.40	1.50	1.20	14	.....	1.50	1.30	1.00	25	1.10	1.50	1.20	.....
4	.....	1.40	1.50	1.20	15	.....	1.50	(a)	.90	26	1.10	1.50	1.20	.....
5	.....	1.40	1.50	1.20	16	.....	1.50	(a)	.90	27	1.10	1.50	1.20	.....
6	.....	1.50	1.40	1.20	17	.....	1.50	1.30	.80	28	1.10	1.50	1.20	.....
7	.....	1.50	1.40	1.20	18	.....	1.50	1.30	.80	29	1.10	1.50	1.20	.....
8	.....	1.50	1.30	1.00	19	.....	1.50	1.20	.80	30	1.30	1.50	1.20	.....
9	.....	1.50	1.30	1.00	20	.....	1.50	1.20	.....	31	1.30	.....	1.20	.....
10	.....	1.50	1.30	1.00	21	0.90	1.50	1.20	.....					
11	.....	1.50	1.30	1.00	22	.90	1.50	1.20	.....					

a Dry.

Daily gage height, in feet, of Community ditch, Colorado, for 1899.

Day.	Apr.	May.	June.	July.	Day.	Apr.	May.	June.	July.	Day.	Apr.	May.	June.	July.
1	.....	2.10	2.20	2.20	12	.....	2.20	2.20	2.10	23	1.50	2.20	2.20	.....
2	.....	2.10	2.30	2.20	13	.....	2.20	2.20	2.10	24	1.70	2.20	2.20	.....
3	.....	2.10	2.30	2.20	14	.....	2.20	2.20	2.10	25	1.80	2.20	2.20	.....
4	.....	2.20	2.30	2.20	15	.....	2.20	2.20	.....	26	1.80	2.20	2.20	.....
5	.....	2.20	2.30	2.20	16	.....	2.20	2.20	.....	27	1.90	2.20	2.20	.....
6	.....	2.20	2.20	2.20	17	.....	2.20	2.20	1.25	28	1.90	2.20	2.20	.....
7	.....	2.20	2.20	2.20	18	.....	2.20	2.20	1.30	29	2.10	2.20	2.20	.....
8	.....	2.20	(a)	2.20	19	.....	2.20	2.20	1.20	30	2.10	2.20	2.20	.....
9	.....	2.20	2.20	2.10	20	.....	2.10	2.20	1.20	31	.....	2.20	.....	.....
10	.....	2.20	2.20	2.10	21	.....	2.10	2.20	1.20					
11	.....	2.20	2.20	2.10	22	.....	2.20	2.20	1.20					

a Dry.

BOULDER CREEK AT BOULDER, COLORADO.

The next drainage of importance entering the South Platte from the west is Boulder Creek, an important tributary, furnishing water for a number of irrigation ditches. The station is located about 1½ miles above the town of Boulder, Colorado. The gage rod is inclined and spiked to stakes driven into the ground. The bench mark is the top of a large stone 22 feet west of the gage, and is 5.72 feet above gage datum. Both banks are high and rocky, and not liable to overflow. Two small irrigating ditches take water from the stream above the station, but the amount thus diverted will probably not exceed 5 or 6 second-feet. Results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 171; 1897, Nineteenth Annual Report, Part IV, page 319; 1898, Twentieth Annual Report, Part IV, page 286. The following discharge measurements were made under the direction of A. L. Fellows in 1899:

April 21, gage height, 1 foot; discharge, 84 second-feet.
May 6, gage height, 1.20 feet; discharge, 134 second-feet.
June 15, gage height, 2.50 feet; discharge, 642 second-feet.
August 10, gage height, 1.70 feet; discharge, 276 second-feet.
October 10, gage height, 0.50 foot; discharge, 36 second-feet.

Daily gage height, in feet, of Boulder Creek at Boulder, Colorado, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	0.32	1.55	2.15	2.90	1.92	1.52	0.48	0.48
2	.30	1.52	2.12	2.92	1.98	1.50	.48	.45
3	.38	1.40	2.12	2.85	2.22	1.45	.48	.48
4	.45	1.38	2.00	2.85	2.45	1.38	.48	.48
5	.35	1.30	1.98	2.78	2.18	1.22	.45	.42
6	.32	1.20	2.05	2.70	2.02	1.12	.48	.40
7	.42	1.22	2.12	2.65	1.88	1.05	.42	.38
8	.42	1.28	2.18	2.58	1.82	.95	.45	.38
9	.48	1.35	2.28	2.48	1.78	.98	.50	.35
10	.55	1.45	2.45	2.50	1.70	.95	.55	.35
11	.92	1.60	2.48	2.42	1.05	.92	.58	.30
12	1.00	1.70	2.62	2.40	1.68	.90	.60	.30
13	1.05	1.90	2.65	2.48	1.62	.88	.65	.35
14	1.10	2.00	2.68	2.45	1.52	.95	.65	.38
15	1.10	2.12	2.62	2.48	1.60	.98	.60	.42
16	1.25	2.15	2.58	2.40	1.65	.92	.58	.42
17	1.20	2.12	2.60	2.30	1.55	.88	.58	.40
18	1.22	2.08	2.75	2.28	1.52	.82	.52	.35
19	1.15	2.12	2.85	2.18	1.45	.78	.55	.30
20	1.10	2.15	2.85	2.12	1.38	.72	.50	.30
21	1.12	2.10	2.90	2.10	1.38	.72	.48	.28
22	1.20	2.08	2.88	2.05	1.32	.62	.50	.28
23	1.25	2.10	2.90	2.02	1.32	.60	.52	.25
24	1.48	2.05	2.85	1.90	1.28	.58	.55	.25
25	1.62	2.08	2.85	1.92	1.20	.58	.60	.22
26	1.68	2.18	2.85	2.00	1.15	.55	.55	.22
27	1.65	2.12	2.78	2.05	1.22	.58	.50	.25
28	1.60	2.12	2.70	2.10	1.45	.55	.48	.22
29	1.55	2.15	2.72	2.20	1.25	.50	.48	.18
30	1.58	2.15	2.82	2.10	1.50	.50	.48	.18
31	.....	2.12	.....	1.90	1.55	.....	.50	.....

ST. VRAIN CREEK AT LYONS, COLORADO.

The gaging station on this drainage is located one-half mile southeast of Lyons, Colorado, below the intersections of the North and South forks of St. Vrain Creek. The gage is inclined and fastened to a post driven into the ground. Both banks are low and liable to overflow. The bed of the stream is composed of gravel. On May 5 a new gage rod was established having the same reading as the old one, and connected with a bench mark 150 feet north of the rod. The elevation of the bench mark is 6.51 feet above gage datum. Supply ditch diverts water above the station, and its discharge should be added to that of the river to obtain the total run-off in the basin. On May 5 at the rating flume, it was discharging, at a gage height of 0.65 foot, 35 second-feet. The observer is Miss Bessie Sites, who reads the gage on the creek, as well as that of the ditch. The results of measurements are found as follows: 1896, Eighteenth Annual Report, Part IV, page 173; 1897, Nineteenth Annual Report, Part IV, page 320; 1898, Twentieth Annual Report, Part IV, page 285. The following discharge measurements were made under the direction of A. L. Fellows in 1899:

April 18, gage height, 3 feet; discharge, 217 second-feet.
May 5, gage height, 2.75 feet; discharge, 137 second-feet.
June 14, gage height, 4.15 feet; discharge, 825 second-feet.
August 9, gage height, 3.20 feet; discharge, 263 second-feet.
October 7, gage height, 2.10 feet; discharge, 37 second-feet.

Daily gage height, in feet, of St. Vrain Creek at Lyons, Colorado, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	2.05	2.90	3.35	4.40	3.45	2.65	2.05	2.00
2	2.15	2.90	3.55	4.40	3.45	2.65	2.05	2.00
3	2.25	2.70	3.45	4.30	3.60	2.60	2.05	2.00
4	2.25	2.55	3.45	4.30	4.05	2.55	1.95	2.00
5	2.20	2.65	3.45	4.30	4.05	2.55	1.95	2.00
6	2.25	2.90	3.40	4.15	3.85	2.55	1.95	2.00
7	2.30	3.00	3.50	4.00	3.75	2.55	1.95	1.95
8	2.25	2.90	3.50	4.05	3.70	2.65	1.95	1.90
9	2.35	3.00	3.55	4.15	3.65	2.65	2.05	1.90
10	2.70	3.10	3.50	4.05	3.55	2.65	2.05	1.90
11	2.75	3.15	3.75	4.05	3.50	2.65	2.15	1.90
12	2.80	3.35	4.05	3.95	3.40	2.55	2.18	1.95
13	3.00	3.30	4.00	4.00	3.20	2.55	2.15	2.00
14	3.05	3.40	4.25	4.10	3.05	2.55	2.25	2.00
15	3.00	3.40	4.10	4.00	2.95	2.55	2.25	2.00
16	2.90	3.35	4.15	3.90	2.90	2.45	2.25	2.00
17	3.10	3.30	4.30	3.65	2.90	2.45	2.22	2.10
18	3.10	3.30	4.50	3.65	2.95	2.35	2.22	2.05
19	3.20	3.30	4.55	3.65	2.80	2.35	2.15	2.00
20	3.15	3.35	4.65	3.65	2.90	2.25	2.15	2.00
21	3.15	3.25	4.55	3.65	2.90	2.30	2.15	2.00
22	3.20	3.20	4.55	3.65	2.90	2.22	2.15	2.00
23	3.40	3.25	4.30	3.65	2.80	2.25	2.25	2.00
24	3.65	3.25	4.25	3.55	2.80	2.25	2.25	1.95
25	3.65	3.05	4.25	3.60	2.70	2.20	2.25	1.95
26	3.55	3.10	4.30	3.55	2.60	2.18	2.15	1.95
27	3.65	3.40	4.25	3.55	2.60	2.18	2.15	1.90
28	3.45	3.40	4.25	3.60	2.55	2.15	2.05	1.90
29	3.30	3.30	4.35	3.70	2.65	2.12	2.05	1.90
30	3.15	3.40	4.30	3.45	2.65	2.05	2.15	1.90
31	.....	3.30	.....	3.45	2.55	.....	2.15	(a)

a Closed for the winter November 30.

Daily gage height, in feet, of Supply ditch at Lyons, Colorado, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	0.10	0.90	0.70	1.40	0.90	0.58	0.15	0.10
2	.10	.80	.70	1.40	.90	.52	.15	.10
3	.10	.70	.70	1.40	.85	.55	.15	.10
4	.10	.70	.70	1.40	.80	.50	.15	.10
5	.10	.70	.60	1.40	.80	.52	.10	.10
6	.10	.70	.50	1.30	.80	.37	.10	.10
7	.10	.70	.50	1.30	.80	.20	.10	.10
8	.10	.70	.50	1.30	.80	.40	.10	.10
9	.10	.70	.55	1.30	.80	.40	.10	.10
10	.25	.70	.60	1.30	.80	.20	.10	.10
11	.40	.70	.95	1.30	.80	.20	.20	.10
12	.40	.95	1.20	1.25	.80	.20	.20	.10
13	.40	.80	1.30	1.20	.85	.28	.20	.10
14	.40	.80	1.30	1.20	.70	.22	.15	.10
15	.45	.80	1.40	1.20	.70	.20	.10	.10
16	.50	.80	1.40	1.20	.70	.20	.10	.10
17	.50	.90	1.40	1.20	.70	.20	.10	.10
18	.10	1.00	1.40	1.20	.70	.20	.10	.10
19	.10	1.00	1.40	1.20	.70	.30	.10	.10
20	.10	1.00	1.40	1.20	.70	.20	.10	.10
21	.10	1.00	1.40	1.05	.50	.20	.10	.10
22	.10	1.00	1.40	.90	.50	.20	.10	.10
23	.10	1.00	1.40	.90	.50	.18	.10	.10
24	.10	.70	1.40	.90	.50	.18	.10	.10
25	.10	.40	1.40	.90	.50	.12	.15	.10
26	.10	.60	1.40	.90	.50	.10	.15	.10
27	.10	.80	1.40	.90	.50	.10	.15	.10
28	.10	.80	1.40	.90	.20	.10	.15	.10
29	.10	.75	1.40	.90	.20	.15	.10	.10
30	.50	.70	1.40	.90	.50	.15	.10	.10
31	.....	.70	.....	.90	.60	.....	.10	.....

BIG THOMPSON CREEK AT ARKINS, COLORADO.

This stream drains the country immediately south of the headwaters of Cache la Poudre River, and enters the South Platte 8 miles from Greeley. The location of the station was changed April 1, 1899, from its original position to a point 2 miles above, so that the head of the Home Supply ditch is now below the gaging station, while that of the Handy ditch is still above. It is necessary to include the discharge of this latter canal to give the total run-off of the stream. The present location of the station is at a wagon bridge upon the ranch of Mr. John Chasteen. The gage rod consists of a 2 by 4 inch timber spiked to the downstream side of the bridge on the right-hand side of the river. The bench mark is 25 feet south of the gage and is 9.35 feet above the zero. Handy ditch, which heads one-half mile above the station, was measured twice during the year, the first time, on April 17, at a gage height 0.6 foot, the discharge was 41 second-feet; June 13, at a gage height of 2.30 feet, the discharge was 182 second-feet. The observer is Ed. Chasteen, who records the heights of the canal as well as at the main gaging station. The results of measurements are found as follows: 1896, Eighteenth Annual Report, Part IV, page 175; 1897, Nineteenth Annual Report, Part IV, page 322; 1898, Twentieth Annual Report, Part IV, page 288. The following discharge measurements were made under the direction of A. L. Fellows in 1899:

April 17, gage height, 0.90 foot; discharge, 143 second-feet.
May 4, gage height, 0.97 foot; discharge, 173 second-feet.
June 13, gage height, 2.55 feet; discharge, 941 second-feet.
August 8, gage height, 1.73 feet; discharge, 406 second-feet.
October 6, gage height, 0.50 foot; discharge, 34 second-feet.

Daily gage height, in feet, of Big Thompson Creek at Arkins, Colorado, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	0.30	1.00	1.90	2.75	1.80	0.90	(a)
2	.40	.95	2.00	2.70	1.80	.90	(a)
3	.35	.90	1.90	2.60	1.80	.85	(a)
4	.45	.90	1.85	2.65	2.15	.80	(a)
5	.45	.90	1.90	2.50	1.90	.90	(a)
6	.50	.90	1.90	2.40	1.80	.85	(a)
7	.55	.90	1.90	2.40	1.75	.80	(a)
8	.35	1.00	2.00	2.30	1.70	.80	0.50
9	.20	1.00	2.10	2.30	1.60	.80	.50
10	.35	1.00	2.15	2.25	1.55	.80	.60
11	.55	1.05	2.25	2.20	1.45	.80	.70
12	.65	1.10	2.30	2.15	1.40	.80	.80
13	.75	1.25	2.45	2.75	1.30	.70	.80
14	.90	1.55	2.60	2.15	1.30	.70	.60
15	.90	1.60	2.65	2.15	1.30	.70	.60
16	.95	1.65	2.75	2.25	1.25	.70	.60
17	.95	1.50	2.80	1.95	1.20	.70	.60
18	.95	1.40	2.80	1.75	1.15	.80	.60
19	1.00	1.40	2.90	2.00	1.20	.70	.60
20	1.10	1.45	3.15	2.00	1.10	.70	.60
21	1.00	1.60	3.15	1.90	1.10	.60	.60
22	1.15	1.40	2.90	2.00	1.05	.60	.60
23	1.20	1.60	2.65	2.00	1.00	.60	.60
24	1.35	1.75	2.50	2.05	1.05	.60	.60
25	1.30	1.85	2.60	1.90	1.00	.65	.60
26	1.45	1.85	2.65	1.85	1.00	.55	.60
27	1.50	2.00	2.55	1.95	.90	.50	.60
28	1.45	2.00	2.70	1.90	.95	.50	.60
29	1.25	1.90	2.80	1.90	.90	.50	.60
30	1.10	1.90	2.75	1.90	.90	.50	.60
31	.....	2.00	.....	1.80	.90	.....	.60

a No readings; closed for the winter October 31.

Daily gage height, in feet, of Handy ditch on Big Thompson Creek, Colorado, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Day.	Apr.	May.	June.	July.	Aug.	Sept.
1	.....	0.30	0.95	2.30	0.75	0.30	17	.....	1.10	2.20	1.92	0.70	(a)
2	.....	.30	.95	2.30	.75	.30	18	.....	2.00	2.20	1.55	.70	(a)
3	.....	.30	.72	2.30	.75	.30	19	.....	2.00	2.30	1.55	.70	(a)
4	.....	.55	.60	2.30	1.12	.30	20	.....	1.15	2.30	1.15	.70	(a)
5	.....	.80	.60	2.30	1.55	.30	21	.....	1.15	2.30	.75	.70	.30
6	.....	.78	.70	2.30	1.15	.30	22	.....	.75	2.30	.75	.70	.30
7	.....	.75	.75	2.30	1.55	.30	23	.....	.75	2.30	.75	.70	.30
8	.....	.75	.78	2.30	1.30	.30	24	.....	.75	2.25	.75	.70	.50
9	.....	.75	1.10	2.30	1.02	.30	25	0.30	.75	2.30	.75	.50	.40
10	.....	.75	1.55	2.30	.75	.30	26	.30	.75	2.30	.75	.30	.30
11	.....	.75	2.00	2.30	.70	.30	27	.30	.98	2.30	1.12	.30	.30
12	.....	.75	2.00	1.95	.70	.30	28	.30	.98	2.30	1.50	.30	.30
13	.....	.75	2.10	1.95	.70	.30	29	.30	.98	2.30	1.50	.30	.30
14	.....	2.20	2.20	2.30	.70	.30	30	.30	.75	2.30	1.50	.30	.30
15	.....	2.20	2.20	2.30	.70	.65	31	.....	.75	.....	1.13	.30	.....
16	.....	1.60	2.20	2.30	.70	1.00							

a Dry.

CACHE LA POUDRE RIVER AT FORT COLLINS, COLORADO.

This stream drains an area of considerable size in northern Colorado, its headwater tributaries joining those of Laramie on the west. As given in the description of this latter stream, the Sky-line Canal diverts water from the Laramie River into Cache la Poudre River, and measurements of discharge in the latter basin include some of the Laramie waters. The station was established in 1884, at a point about 15 miles above Fort Collins, by Prof. L. G. Carpenter, of the Colorado State Agricultural College, and the work has been carried on under his immediate direction. The record is probably the longest and among the best of any of the small streams of the West. The daily discharge for 1893 and 1894 will be found in Bulletin No. 131, page 30. The following table shows the daily discharge through the irrigating season of the river from 1895 to 1899, inclusive:

Daily discharge, in second-feet, of Cache la Poudre River at Fort Collins, Colorado.

1895.

Day.	May.	June.	July.	Aug.	Sept.	Day.	May.	June.	July.	Aug.	Sept.
1	.....	1,800	1,690	796	357	17	1,100	.....	1,030	417	180
2	.....	1,920	1,510	805	339	18	1,100	.....	996	389	174
3	.....	3,200	1,430	846	300	19	1,350	.....	950	380	180
4	.....	2,800	1,410	666	283	20	.....	.....	942	406	188
5	.....	2,500	1,368	612	264	21	.....	.....	996	398	200
6	.....	2,660	1,240	588	247	22	.....	.....	1,076	375	216
7	.....	2,750	1,210	565	238	23	1,300	.....	1,086	404	216
8	.....	2,940	1,100	541	229	24	1,274	.....	899	415	208
9	.....	3,130	1,065	676	212	25	1,325	.....	867	381	.....
10	.....	3,450	1,114	652	192	26	1,404	.....	800	378	.....
11	.....	3,100	1,200	558	196	27	1,512	1,740	768	312	.....
12	.....	2,500	1,682	512	194	28	2,060	1,920	722	326	.....
13	.....	.....	1,602	471	192	29	1,668	1,830	707	343	.....
14	.....	.....	1,352	487	192	30	1,500	1,715	722	349	.....
15	1,690	.....	1,220	480	188	31	1,400	.....	.....	378	.....
16	.....	.....	1,142	447	184						

1896.

Day.	June.	July.	Aug.	Sept.	Day.	June.	July.	Aug.	Sept.
1	.....	531	364	322	17	981	617	320	255
2	.....	538	322	283	18	942	602	192	251
3	.....	512	288	308	19	882	468	320	280
4	.....	487	289	298	20	878	403	294	294
5	.....	468	284	288	21	841	364	283	285
6	.....	456	269	260	22	780	348	422	255
7	.....	432	260	233	23	753	362	517	.....
8	.....	507	238	208	24	753	495	390	.....
9	.....	480	216	268	25	760	453	302	.....
10	.....	409	196	370	26	745	498	269	.....
11	.....	396	173	411	27	707	589	251	.....
12	.....	381	173	381	28	634	468	242	.....
13	.....	381	169	346	29	612	456	266	.....
14	.....	395	166	307	30	559	415	288	.....
15	.....	394	162	278	31	.....	392	358	.....
16	.....	499	158	264					

Daily discharge, in second-feet, of Cache la Poudre River at Fort Collins, Colorado—Continued.

1897.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1		862	3,013	994	466		a 121
2		964	2,378	910	437		
3		978	1,906	1,051		203	
4		1,171	1,681	945			
5		1,189	1,601	792			
6		1,268	1,485	769	a 420		
7		1,425	1,406	797			
8		1,517	1,451	848			
9		1,486	1,961	1,048			
10		1,474	2,191	1,039		186	
11			2,173	971			
12			2,232	837			
13			2,402	797	a 339		
14			2,074	772			
15			2,328	1,028			
16			2,451	907			
17			1,698	828			
18		2,236	1,381	791			
19		2,296	1,449	816			
20		2,857	1,533	738	a 314		
21		3,106	1,548	626			
22		2,654		558			
23		2,987	1,463	520			
24		3,155	1,308	650		142	
25		2,981	1,339	546			
26		2,822	1,468	478			
27	667	2,998	1,278	449	a 248		
28	810	2,461	1,105	441			
29		2,505	1,086	418			
30	704	2,468	1,043	404			
31		2,658		455			

a Average for week.

1898.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1		307	1,148	812	211		a 35
2		271	1,410	792	201		
3		267	1,636	704	180	a 112	
4		243	1,481	645	177		
5		244	1,210	586	186		
6		206	1,035	576	206		
7		219	1,131	554	258		
8		251	1,192	523	220		a 50
9		397	1,267	555	176		
10		337	1,247	592		a 97	
11			1,379	580			
12			1,364	686			
13			1,383	893	a 139		
14			1,612	658			
15			1,411	571			a 66
16			1,605	521			
17			1,658	486		a 60	
18		806	1,629	437			
19		756	1,650	396			
20		755	1,432	332	a 133		
21		664	1,414	319			
22		629		297			a 84
23		702	1,349	288			
24		837	1,358	287		a 43	
25		1,308	1,273	296			
26		1,175	1,109	283			
27	294	1,050	951	267	a 115		
28	308	1,280	905	240			
29		1,130	842	212			
30	316	1,115	824	211			
31		1,265		210			

a Average for week.

Daily discharge, in second-feet, of Cache la Poudre River at Fort Collins, Colorado—Continued.

1899.

Day.	May.	June.	July.	Aug.	Sept.	Oct.
1	.....	1,848	2,710	767	358	116
2	.....	1,924	2,544	765	351	112
3	.....	1,839	2,459	782	365	104
4	.....	1,631	2,415	972	336	100
5	.....	1,472	2,102	974	324	95
6	.....	1,579	2,242	848	302	93
7	.....	1,786	2,196	813	290	92
8	.....	1,912	1,678	760	280	104
9	.....	2,010	1,577	797	263	111
10	636	2,168	1,482	735	231	125
11	684	2,490	1,308	668	213	.....
12	929	3,103	1,708	629	201	.....
13	1,144	3,619	1,643	592	196	.....
14	1,348	2,831	1,477	555	199	.....
15	1,404	2,702	1,446	504	202	.....
16	1,452	2,822	1,355	682	220	.....
17	1,453	2,981	1,161	533	220	.....
18	1,492	3,040	1,081	489	200	98
19	1,663	3,556	974	431	183	128
20	1,809	3,865	985	399	162	160
21	1,573	3,968	974	381	125	165
22	1,380	3,343	972	344	125	110
23	1,310	2,945	987	307	125	110
24	1,351	2,933	960	301	125	110
25	1,521	2,663	947	286	125	.....
26	1,911	2,953	841	286	123	.....
27	2,001	2,943	955	281	141	.....
28	1,936	2,734	928	328	141	.....
29	1,806	2,691	918	322	126	.....
30	2,015	2,606	897	331	120	.....
31	1,881	.....	809	423	.....	.....

NORTH LOUP RIVER AT ST. PAUL, NEBRASKA.

This stream has its source among the sand hills in the western portion of Cherry County, Nebraska, and drains the country midway between the Niobrara River on the north and Middle Loup River on the south. It has a general southeasterly direction, joining the Middle Loup at St. Paul to form the main Loup River, which enters Platte River near Columbus, Nebraska. Calamus River is a tributary of the North Loup River, entering it near Burwell, Nebraska. The measurement of its discharge at the bridge 1 mile above the mouth and 2 miles north of Burwell, on May 16, 1899, by Glenn E. Smith, showed a discharge of 372 second-feet; North Loup River, on May 16, from a bridge one-fourth of a mile above Burwell, below the mouth of Calamus River, was carrying 984 second-feet. The gaging station on North Loup River, established in 1895, is located at the wagon bridge 4 miles north of St. Paul. Measurements at this station were not made in 1898, but the station was resumed April 18, 1899, when a new rod was located 200 feet downstream from the line of the hand rail on the wagon bridge. It is a 2 by 3 inch timber, 16 feet long, situated on the left bank of the river, at an angle of 30°. The bench mark is the standard iron pipe, with brass cap, of the United States Geological Survey. It is set with the top 5 inches above the ground, and 102 feet northwest of the gage rod, and is at an elevation of 5.57 feet above gage datum. The zero of the old rod

was 6.54 feet below same bench; so that 0.97 foot should be added to all gage heights after April 18, 1899, to make them comparable with the previous records. The bed of the river is sandy and is liable to change during floods. James Stout, jr., a farmer living about a quarter of a mile from the rod, is the observer. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 176; 1897, Nineteenth Annual Report, Part IV, page 329; 1898, no report. The following discharge measurements were made by Glenn E. Smith during 1899:

Measurements of North Loup River at St. Paul, Nebraska.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Sec. feet.*	1899.	*Feet.*	*Sec. feet.*
Apr. 18	1.81	1,678	Aug. 8	1.70	1,028
May 5	1.77	1,138	Aug. 23	1.47	920
May 18	1.65	877	Sept. 7	1.70	917
June 7	1.58	1,024	Sept. 19	1.50	796
June 27	3.40	7,690	Sept. 30	1.47	776
July 20	1.35	811			

Daily gage height, in feet, of North Loup River at St. Paul, Nebraska, for 1899. a

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	.....	1.85	1.68	1.95	1.34	1.61	1.52
2	.....	1.85	1.65	1.83	1.37	1.68	1.58
3	.....	1.83	1.66	1.75	1.38	1.73	1.55
4	.....	1.80	1.62	1.68	1.89	1.57	1.55
5	.....	1.80	1.61	1.68	2.20	1.62	1.57
6	.....	1.75	1.60	1.59	2.08	1.70	1.52
7	.....	2.30	1.55	1.55	2.05	1.95	1.50
8	.....	2.32	1.57	1.55	2.01	1.98	1.50
9	.....	2.07	1.56	1.56	1.88	1.85	1.60
10	.....	2.00	1.52	1.57	1.80	1.80	1.63
11	.....	1.95	1.55	1.63	1.92	1.72	1.58
12	.....	1.88	1.53	1.53	1.74	1.68	1.53
13	.....	1.72	1.47	1.49	1.92	1.65	1.57
14	.....	1.72	1.42	1.45	1.86	1.62	1.55
15	.....	1.68	1.41	2.12	1.65	1.60	2.08
16	.....	1.71	1.45	2.27	1.65	1.63	2.08
17	.....	1.73	1.48	2.08	1.57	1.53	1.97
18	1.81	1.70	1.50	1.92	1.48	1.55	1.69
19	1.77	1.64	1.50	1.75	1.55	1.50	1.65
20	1.82	1.68	1.50	1.35	1.57	1.50	1.65
21	1.73	2.30	1.47	1.37	1.62	1.50	1.60
22	1.75	2.08	1.50	1.28	1.58	1.51	1.58
23	1.72	1.93	1.53	1.30	1.57	1.50	1.60
24	1.80	1.90	2.30	1.28	1.54	1.55	1.60
25	1.83	1.87	2.00	1.28	1.54	1.52	1.62
26	1.78	1.85	1.80	1.33	1.55	1.50	1.60
27	3.20	1.78	3.30	1.32	1.57	1.52	1.65
28	2.78	1.75	2.54	1.25	1.53	1.55	1.63
29	2.43	1.77	2.12	1.22	1.54	1.55	1.58
30	1.87	1.73	2.08	1.33	1.57	1.58	1.57
31	.....	1.73	.....	1.36	1.59	.....	1.58

a Closed for winter October 31.

MIDDLE LOUP RIVER AT ST. PAUL, NEBRASKA.

This river also has its source in the sand hills of Cherry County, and flows in a general southeasterly direction, joining the North Loup River at St. Paul. Oak Creek is a small stream draining the area east of Loup City and flowing southeasterly into the Middle Loup.

It was measured by Glenn E. Smith, on May 19, 1899, at a point above the backwater from the dam, at which time it showed a discharge of 5 second-feet. The original station was established May 5, 1895, by Glenn E. Smith, but was discontinued during 1898. It was reestablished, however, on April 18, 1899, and is located at the highway and railway bridge about 1 mile south of St. Paul. The rod is located on the right bank of the stream, 130 feet downstream from the line of hand rail of bridge and consists of an oak rod 2 by 3 inches, 16 feet long, set at an angle of 30 degrees. On account of a change in the channel of the river, which threatened to leave the gage rod dry, a second rod was set on the north side on June 7, 1899. The new rod is 2 by 4 inches, hard pine, 12 feet long, set at an angle of 30 degrees, and 200 feet downstream from the bridge. The gage datum is the same for both rods. The observer is instructed to read the rod adjacent to the main channel, on whichever side it may be, and the hydrographer is expected to read both rods. The bench mark is the regulation 4-foot iron post of the United States Geological Survey, and is located 60 feet southeast of the gage rod and 100 feet from the line of the downstream hand rail of the bridge. It is 7.54 feet above gage datum. The zero of the original rod was 7.35 feet below the same bench mark, so that 0.19 foot should be subtracted from all gage heights after April 18, 1899, to make them comparable with the previous records. The observer is A. C. Snyder, a farmer living about one-half mile from the station. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 181; 1897, Nineteenth Annual Report, Part IV, page 330; 1898, no report. The following measurements were made by Glenn E. Smith and Adna Dobson during 1899:

Measurements of Middle Loup River at St. Paul, Nebraska.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Sec. feet.*	1899.	*Feet.*	*Sec. feet.*
Apr. 18	2.10	988	Aug. 7	2.08	1,612
May 4	1.84	964	Aug. 23	2.20	1,113
May 18	1.70	1,186	Sept. 7	2.25	983
June 7	2.30	920	Sept. 19	2.40	1,112
June 27	4.20	14,631	Sept. 30	2.25	989
July 20	2.18	888			

Daily gage height, in feet, of Middle Loup River at St. Paul, Nebraska, for 1899. (a)

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	.....	1.76	1.59	2.00	2.24	2.29	2.24
2	.....	1.80	1.41	1.87	2.12	2.29	2.20
3	.....	1.79	1.40	1.90	2.16	2.33	2.35
4	.....	1.81	1.62	1.90	3.10	2.19	2.34
5	.....	1.95	1.53	2.12	2.74	2.16	2.37
6	.....	1.82	1.44	2.78	2.70	2.21	2.40
7	.....	1.90	1.54	3.17	2.65	2.18	2.37
8	.....	2.08	1.29	2.71	2.57	2.28	2.34
9	.....	1.93	1.32	2.42	2.66	2.32	2.36
10	.....	1.87	1.25	2.16	2.25	2.34	2.38
11	.....	1.81	1.24	2.12	2.20	2.34	2.34
12	.....	1.78	1.20	2.09	2.18	2.32	2.37
13	.....	1.75	1.33	2.18	2.13	2.28	2.36
14	.....	1.75	1.32	3.10	2.25	2.25	2.40
15	.....	1.60	1.31	2.65	2.39	2.30	2.39
16	.....	1.62	1.32	2.55	2.36	2.30	2.49
17	.....	1.62	1.30	2.38	2.31	2.40	2.47
18	2.10	1.72	1.28	2.20	2.30	2.38	2.49
19	2.09	1.66	1.19	2.12	2.27	2.36	2.42
20	2.12	1.70	1.15	2.12	2.21	2.30	2.40
21	2.09	1.80	1.32	2.09	2.20	2.30	2.41
22	2.10	2.15	1.34	2.11	2.15	2.30	2.42
23	2.00	2.05	1.29	2.12	2.20	2.30	2.41
24	2.00	1.70	1.29	2.15	2.20	2.27	2.40
25	2.03	1.68	2.34	2.06	2.15	2.26	2.45
26	2.60	1.60	4.17	2.02	2.19	2.24	2.42
27	2.12	1.83	3.51	2.06	2.16	2.27	2.45
28	2.39	1.92	3.30	2.30	2.12	2.26	2.44
29	2.00	1.66	2.84	2.20	2.10	2.24	2.47
30	1.74	1.49	2.35	2.10	2.13	2.22	2.49
31	.....	1.84	.....	2.42	2.21	.....	2.49

a Closed for winter October 31.

LOUP RIVER AT COLUMBUS, NEBRASKA.

This river is formed by the junction of the North Loup and Middle Loup rivers at St. Paul, Nebraska, and 60 miles below St. Paul enters the Platte River near Columbus, Nebraska. Cedar River is a tributary of Loup River, and flows southeasterly, emptying into Loup River at Fullerton, 30 miles below St. Paul. At Ericson, Nebraska, a large dam has been built for the purpose of turning Cedar Creek into a canal to be used for irrigation. The dam backs the water for about one-half a mile, forming a pond 1,000 feet in width in some places. May 17, 1899, Glenn E. Smith measured the river 500 feet below the above dam, and below the race of a small mill near by, and found a discharge of 113 second-feet; at the same time the mill race was carrying 10 second-feet, and the Cedar Valley irrigation canal 20 second-feet—this latter being measured about 1,000 feet below the head gates. On the same day a measurement was made by wading, at a point 2 miles from Ericson and above the backwater from the dam, and gave a discharge in Cedar River of 107 second-feet. A tributary known as Dry Cedar enters near this point—there being seldom any discharge from it except during the rainy season. Near the mouth of this tributary are several small springs, not large enough, however, to give a continuous discharge. They were found to be flowing on May 17, at a point about 1 mile north of Ericson, 5 second-feet, while 5 miles above the channel was dry. The gaging station

on the Loup River is located near the iron bridge of the Union Pacific Railway just west of Columbus, Nebraska, and only a short distance above the mouth of the river. The gage rod is 150 feet from the bridge, and is of oak, fastened to a pile which forms part of the training works above the bridge. The bench mark is the regulation 4-foot iron post of the United States Geological Survey, placed 72 feet east of the rod, and is 13.27 feet above gage datum. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 182; 1897, Nineteenth Annual Report, Part IV, page 332; 1898, Twentieth Annual Report, Part IV, page 294. The following measurements of discharge were made by Glenn E. Smith during 1899:

Measurements of Loup River at Columbus, Nebraska.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Sec.-feet.*	1899—Continued.	*Feet.*	*Sec.-feet.*
Jan. 22	Frozen.	2,726	July 9	5.40	3,435
Apr. 9	4.95	3,004	July 23	4.25	1,792
Apr. 23	5.00	2,699	Aug. 6	4.98	3,251
May 7	5.05	3,057	Aug. 20	4.61	2,267
May 23	5.54	4,073	Sept. 3	4.40	1,902
June 4	4.86	2,628	Sept. 17	4.40	1,840
June 18	4.75	1,921	Oct. 5	4.60	2,402
June 29	5.80	7,728	Oct. 15	4.80	1,983

Daily gage height, in feet, of Loup River at Columbus, Nebraska, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	.....	5.30	.....	5.50	4.30	4.80	4.40
2	5.40	4.95	5.00	.....	4.25	4.85	4.40
3	5.60	4.60	.....	5.90	4.20	4.80	4.40
4	5.80	4.70	4.80	.....	4.25	4.80	4.40
5	5.70	4.90	.....	5.70	4.55	4.70	4.45
6	5.00	4.95	5.40	.....	4.93	4.60	4.40
7	4.90	5.05	.....	5.60	4.90	4.55	4.40
8	5.00	4.95	.....	.....	4.80	4.50	4.40
9	4.95	5.15	.....	.....	4.85	4.80	4.40
10	4.90	5.00	.....	4.40	4.80	4.70	4.40
11	5.00	4.95	5.40	.....	4.70	4.60	4.40
12	4.90	4.80	.....	4.00	4.85	4.50	4.40
13	4.80	4.85	.....	4.20	4.20	4.45	4.40
14	4.90	4.97	.....	4.21	4.10	4.40	4.50
15	5.10	5.30	.....	4.20	4.50	4.40	4.80
16	5.20	5.15	4.80	4.10	4.20	4.40	4.70
17	5.15	5.14	.....	4.20	4.40	4.40	4.75
18	5.10	4.95	4.70	4.15	4.40	4.40	4.70
19	5.00	5.00	.....	4.00	4.50	4.40	4.60
20	4.90	5.05	.....	3.98	4.61	4.40	4.50
21	4.90	5.40	4.95	4.00	4.80	4.40	4.50
22	4.90	5.80	.....	4.10	4.70	4.40	4.70
23	5.00	5.54	.....	4.25	4.75	4.40	4.60
24	4.90	5.40	5.10	4.20	4.80	4.40	4.60
25	4.85	.....	.....	4.21	4.81	4.40	4.55
26	4.90	.....	.....	4.20	4.80	4.40	4.55
27	5.00	.....	5.90	4.20	4.81	4.40	4.50
28	5.40	.....	.....	4.22	4.80	4.40	4.55
29	5.60	5.40	5.80	4.23	4.70	4.40	4.60
30	5.80	.....	.....	4.50	4.60	4.40	4.65
31	.....	.....	.....	4.40	4.70	.....	4.65

PLATTE RIVER AT COLUMBUS, NEBRASKA.

Lower Platte River is a sandy stream, the bed shifting during the high stages, through which considerable water is lost during the summer season. On September 8 there were only 20 second-feet flowing in the middle channel at the bridge of the Burlington and Missouri Railroad near Central City, Nebraska, this point being 20 miles below Grand Island and 40 miles above Columbus. On September 19, Glenn E. Smith reports that the stream was dry at this point. Mr. Adna Dobson reports the river dry at Grand Island on September 30. The gaging station at Columbus was established in 1895, and is located on the left bank of the main channel of the river, 75 feet above the Meridian bridge south of Columbus. It is about 4 miles above the mouth of the Loup River. The gage consists of an inclined oak timber fastened to cross-ties which are bedded in the bank of the river. The channel is straight both above and below the gage. The bench mark is a standard 4-foot iron post of the United States Geological Survey, and is located 44.5 feet east of the gage, 60 feet north of the north end of the north bridge truss, and 10 feet west of a cottonwood tree 6 inches in diameter. Its elevation is 7.06 feet above gage datum. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 190; 1897, Nineteenth Annual Report, Part IV, page 334; 1898, Twentieth Annual Report, Part IV, page 295. The following discharge measurements were made by Glenn E. Smith and Adna Dobson during 1899:

Measurements of Platte River at Columbus, Nebraska.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Sec.-feet.*	1899.	*Feet.*	*Sec.-feet.*
Jan. 22	.....	Dry.	July 9	4.61	17,082
Feb. 19	.....	55	July 23	3.84	8,694
Apr. 9	3.50	6,736	Aug. 6	4.00	9,450
Apr. 23	3.94	8,210	Aug. 20	2.80	3,338
May 7	4.14	10,121	Sept. 3	.90	93
May 23	3.81	7,878	Sept. 17	.....	15
June 4	4.01	9,294	Oct. 5	.....	Dry.
June 18	4.00	9,279	Oct. 15	.....	8
June 29	4.82	18,631			

Daily gage height, in feet, of Platte River at Columbus, Nebraska, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.
1	.....	3.90	4.30	5.10	3.70	1.20
2	.00	3.73	4.10	4.90	3.65	1.10
3	.00	3.80	4.00	4.80	3.60	.90
4	4.00	3.85	4.01	4.85	3.68	.85
5	4.80	3.93	3.40	4.96	3.88	.80
6	4.50	4.00	3.70	4.98	4.00	.70
7	4.40	4.14	4.00	4.97	3.90	.65
8	3.70	3.96	3.81	4.98	3.96	.60
9	3.45	4.00	3.65	4.61	3.94	.50
10	3.50	3.94	3.64	4.63	3.90	.....
11	3.55	3.87	4.50	4.62	3.80	.....
12	3.60	3.80	4.60	4.60	4.00	.....
13	3.65	3.73	4.80	4.58	3.50	.....
14	3.20	3.68	4.95	4.56	3.40	.....
15	3.10	3.60	4.98	4.50	3.30	.....
16	3.00	3.63	4.99	4.50	2.90	.....
17	3.10	3.41	4.98	4.40	2.95	.....
18	3.20	3.36	4.00	4.23	2.85	.....
19	3.60	3.21	4.00	4.11	2.81	.....
20	3.80	3.30	4.00	4.10	2.80	.....
21	4.00	3.91	4.20	4.00	2.81	.....
22	3.90	4.10	4.40	3.90	2.80	.....
23	3.94	3.81	4.50	3.88	2.75	.....
24	3.50	4.50	4.63	3.80	2.70	.....
25	3.98	4.70	4.40	3.70	2.60	.....
26	4.50	4.90	4.43	3.72	2.55	.....
27	3.90	5.05	4.50	3.74	2.40	.....
28	3.83	4.83	4.75	3.80	2.00	.....
29	3.90	4.70	4.85	3.90	1.60	.....
30	3.93	4.60	5.15	3.92	1.50	.....
31	.....	4.51	.....	3.85	1.35	.....

June 18-20, gage washed out; gage heights estimated. September 10-October 28, sand bar; no readings. Closed for the winter September 9.

ELKHORN RIVER AT NORFOLK, NEBRASKA.

This river rises in the sand hills in Rock County, Nebraska, and flows in a general southeasterly direction, entering the Platte River about 30 miles above its mouth. Two gaging stations are maintained on this river, one at Norfolk, Nebraska, and the other at Arlington, Nebraska. The station at the former place is at the Thirteenth street bridge, 2 miles south of Norfolk and above the mouth of the North Fork of Elkhorn River. The gage consists of an inclined oak timber fastened to cross-ties, which are firmly bedded in the bank of the river. The bench mark is a standard 4-foot iron pipe of the United States Geological Survey, 35 feet west and 7 feet north of the top of gage and 15.5 feet west of an ash tree. Its elevation is 10.70 feet above gage datum. The bed of the river is composed of sand and mud. A number of measurements of the North Fork were made and are given below. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 191; 1897, Nineteenth Annual Report, Part IV, page 335; 1898, Twentieth Annual Report, Part IV, page 296. The following measurements were made by Glenn E. Smith during 1899:

Elkhorn River:

January 26, gage height, frozen; discharge, 272 second-feet.

April 27, gage height, 1.94; discharge, 505 second-feet.

May 10, gage height, 2.01 feet; discharge, 572 second-feet.

Elkhorn River—Continued.

May 25, gage height, 2.72 feet; discharge, 830 second-feet.

July 7, gage height, 1.70 feet; discharge, 427 second-feet.

August 17, gage height, 1.30 feet; discharge, 274 second-feet.

September 25, gage height, 1.12 feet; discharge, 184 second-feet.

North Fork of Elkhorn River:

February 20, discharge, 119 second-feet.

April 27, discharge, 122 second-feet.

May 25, discharge, 414 second-feet.

August 17, discharge, 81 second-feet.

September 25, discharge, 85 second-feet.

Daily gage height, in feet, of Elkhorn River at Norfolk, Nebraska, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	.....	1.94	2.07	2.45	1.20	0.97	1.13
2	.....	2.24	2.03	2.20	1.23	.97	1.19
3	.....	2.30	1.93	1.97	1.27	.76	1.23
4	.....	3.20	1.85	1.66	1.32	.70	1.26
5	.....	2.41	1.85	1.76	1.33	.67	1.22
6	.....	2.31	1.87	1.74	1.33	1.06	1.23
7	1.90	2.24	2.45	1.68	1.36	1.08	1.22
8	1.87	2.16	2.22	1.71	1.35	1.12	1.27
9	1.90	2.06	1.92	1.67	1.45	1.15	1.28
10	1.93	2.00	1.82	1.73	1.27	1.13	1.25
11	2.00	1.92	1.75	1.73	1.28	1.13	1.20
12	2.01	1.83	1.74	1.78	1.48	1.10	1.20
13	2.05	1.78	1.64	1.69	1.48	1.06	1.29
14	2.05	1.73	1.63	1.65	1.33	1.02	1.27
15	2.03	1.77	1.64	1.56	1.34	1.06	1.33
16	1.98	1.77	1.65	1.51	1.33	1.11	1.30
17	1.98	1.74	1.60	1.48	1.38	1.09	1.32
18	1.97	1.70	1.53	1.45	1.26	1.11	1.31
19	1.99	1.80	1.57	1.43	1.25	1.04	1.32
20	1.90	3.50	1.57	1.45	1.23	1.08	1.34
21	1.97	3.58	1.57	1.38	1.25	1.02	1.33
22	1.89	3.34	1.53	1.34	1.23	1.03	1.33
23	1.85	2.63	1.45	1.26	1.17	1.04	1.33
24	1.84	2.65	1.55	1.21	1.17	1.17	1.31
25	1.84	2.75	2.07	1.23	1.14	1.11	1.36
26	1.87	2.80	1.75	1.23	1.13	1.10	1.31
27	1.93	2.85	2.65	1.24	1.12	1.12	1.34
28	1.95	2.75	3.75	1.24	.97	1.12	1.34
29	1.89	2.35	3.40	1.24	.95	1.13	1.31
30	1.73	2.20	3.02	1.21	.99	1.12	1.32
31	.....	2.07	.....	1.22	.97	.....	1.30

Closed for winter October 31.

ELKHORN RIVER AT ARLINGTON, NEBRASKA.

The station at Arlington, Nebraska, was established by Glenn E. Smith April 28, 1899, and is located at the wagon bridge 1 mile west of the town of Arlington. The original rod was fastened to cross-ties, which are solidly bedded in the river bank. It consisted of a new oak stake 3 by 4 inches and 12 feet long. It was placed 200 feet downstream from the bridge on the west bank of the river. Bench mark No. 1 is a large spike driven in a pile 50 feet upstream from the rod, and is 6.36 feet above gage datum. Bench mark No. 2 is a large spike driven in a piling 20 feet back and 10 feet upstream from the rod, and is 9.12 feet above gage datum. Bench mark No. 3 is a vertical spike driven into a small leaning tree 5 feet downstream from the rod, and is 7.43 feet above gage datum. On May 10 the rod was washed out; on May

29 it was replaced by an oak rod 2 by 6 inches and 16 feet long. This rod was placed on the same bank as the first rod, but was set 25 feet farther upstream. The gage datum was not changed. S. P. Hammang, a farmer living about 300 yards from the gage rod, is the observer. The following discharge measurements were made by Glenn E. Smith during 1899:

Measurements of Elkhorn River at Arlington, Nebraska.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Sec.-feet.*	1899.	*Feet.*	*Sec.-feet.*
Feb. 4		337	July 8	2.23	1,016
Feb. 17		269	Aug. 9	1.72	732
Apr. 28	1.78	794	Aug. 18	1.40	606
May 9	3.90	1,779	Sept. 15	.82	344
May 24		1,626	Sept. 24	.75	340
May 29	4.24	2,462	Oct. 13	.90	351
June 22	2.70	1,199			

Daily gage height, in feet, of Elkhorn River at Arlington, Nebraska, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1		1.84	3.81	2.68	1.32	0.87	0.68
2		2.07	3.65	2.68	1.25	.89	.69
3		1.86	3.63	3.19	1.17	.76	.68
4		1.96	3.50	2.97	1.36	.73	.67
5		2.30	3.41	2.81	1.50	.70	.68
6		3.00	3.42	2.66	1.40	.72	.73
7		4.37	3.54	2.38	1.56	.74	.74
8		3.96	2.87	2.23	2.00	.75	.78
9		3.91	2.58	2.23	1.70	.74	.79
10		(a)	2.38	2.12	1.57	.79	.82
11		(a)	2.35	2.13	1.66	.80	.86
12		(a)	2.40	2.02	1.40	.82	.88
13		(a)	5.35	2.10	1.41	.81	.90
14		(a)	4.94	1.94	1.35	.84	.92
15		(a)	4.55	1.86	1.42	.79	.93
16		(a)	4.12	1.83	1.49	.75	.94
17		(a)	4.30	1.76	1.48	.74	.92
18		(a)	4.48	1.68	1.39	.73	.91
19		(a)	3.67	1.64	1.27	.73	.92
20		(a)	3.16	1.63	1.24	.65	.96
21		(a)	2.67	1.57	1.09	.66	.96
22		(a)	2.76	1.50	1.10	.69	1.02
23		(a)	2.75	1.55	1.09	.72	1.04
24		(a)	2.65	1.36	1.21	.75	1.10
25		(a)	2.51	1.30	1.23	.76	1.12
26		(a)	2.21	1.27	1.08	.70	1.11
27		(a)	2.32	1.27	1.02	.69	1.12
28	1.78	(a)	2.19	1.25	1.07	.66	1.13
29	1.76	4.24	2.32	1.26	1.03	.64	1.12
30	1.81	4.15	2.64	1.20	1.01	.65	1.13
31		4.17		1.22	.85		1.11

Closed for winter October 31. a Rod washed out.

REPUBLICAN RIVER AT SUPERIOR, NEBRASKA.

This river rises in the northeastern part of Colorado, and after entering Nebraska it flows in a general easterly direction along the southern boundary of the State to 98° west longitude, where it bends into Kansas, and thence flows southeasterly until it joins the Smoky Hill River at Junction to form the Kansas River. All of the tributaries of the Kansas River have their sources in the Great Plains

region, none drawing their supply from a mountain area. They are also different from ordinary streams, in that the rainfall is less at the headwaters, gradually increasing downstream. Two gaging stations are maintained on Republican River, one at Superior, Nebraska, just before it enters Kansas, and the other at Junction, Kansas. The former station was established June 20, 1896, about one mile west from Superior, Nebraska. The old gage rod was first placed just above the river highway bridge, which is itself 75 yards above the dam which diverts water into the mill race. In the spring of 1898 two other gages were located and have been exclusively used during the last season. The first gage was placed in the river a few feet upstream from the crest of the dam the zero being at same elevation as the crest, the second is in the mill race, where it is crossed by a wagon bridge about 50 yards below its head. Discharge measurements of the river are made from the highway bridge, thus determining at once the discharge through the mill race and from the dam. The discharge from the mill race was measured in order that it might be deducted from the total discharge of the river to give the amount passing over the dam. The bench mark for the river gage is a standard 4-foot iron post of the United States Geological Survey, and is situated 83 feet north of the upstream cylinder of the north pier of the bridge, and 1 foot inside of a wire fence. Its elevation is 4.92 feet above datum of gage at dam. The gage of the mill race reads 2 feet higher than that of the river gage, so that its zero is 6.92 feet below the same bench mark. During 1899 Glenn E. Smith made an examination of a portion of the upper Republican River. On September 6, at Oxford, Nebraska, the river channel was dry and was reported to have been in this condition for ten days. At Orleans, about 12 miles below, there was an estimated discharge of 0.3 second-feet—this small amount coming from Sappa River, which enters at this point. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 201; 1897, Nineteenth Annual Report, Part IV, page 339; 1898, Twentieth Annual Report, Part IV, page 317. The following discharge measurements were made by Glenn E. Smith during 1899:

Measurements of Republican River at Superior, Nebraska.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Foot.*	*Sec.-feet.*	1899.	*Foot.*	*Sec.-feet.*
January 24	Frozen.	463	June 26	0.42	204
February 14	Frozen.	131	July 6	.90	732
April 10	0.98	738	July 26	.23	135
May 1	.75	382	August 11	.40	215
May 13	.61	442	September 6	.....	0
June 2	.51	291	September 29	.....	0
June 16	.63	439	October 17	.....	0

Measurements of mill race at Superior, Nebraska.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Sec.-feet.*	1899.	*Feet.*	*Sec.-feet.*
April 10	2.98	49	July 6	2.80	56
May 1	3.00	0	August 11	2.70	56
May 13	3.10	47	September 6	2.60	50
June 2	2.60	55	September 29	1.20	25
June 16	3.50	53	October 17	1.50	50
June 26	3.40	59			

No water was passing over the dam, and all was in the mill race on September 6 and 29 and October 17. The figures which are noted as gage heights in the mill race during 1899 are, in fact, measurements of the center depth at the gaging section. As expected, this has proved to be a better basis for the computation of areas of cross section there than the gage height observed in previous years.

Daily gage height, in feet, of Republican River at Superior, Nebraska, for 1899.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1		0.97	0.74	0.45	1.05	0.91	0.12	(a)
2		1.00	.70	.51	.90	.95	.09	(a)
3		.95	.73	.60	.80	.82	.20	(a)
4		.94	1.18	.60	.80	.68	(a)	(a)
5		1.00	.68	.47	.79	.60	(a)	(a)
6		.98	.64	.45	.90	.45	(a)	(a)
7		1.04	.50	.47	.93	.52	(a)	(a)
8		.97	.61	.45	.89	.42	(a)	(a)
9		1.00	.68	.40	.63	.41	(a)	(a)
10		.97	.63	.40	.51	.41	(a)	(a)
11		.94	.63	.41	.45	.40	(a)	(a)
12		.89	.60	.35	.42	.41	(a)	(a)
13		.90	.61	.33	.52	.50	(a)	(a)
14		.90	.67	.70	.47	.60	(a)	(a)
15		.88	.63	.53	.42	.44	(a)	(a)
16		.74	.69	.63	.45	.39	(a)	(a)
17		.83	.65	.42	.45	.62	(a)	(a)
18		.83	.64	.41	.46	.52	(a)	(a)
19	1.13	.82	.65	.12	.39	.42	(a)	(a)
20	.94	.77	.93	.35	.40	.41	(a)	(a)
21	.89	.82	1.50	.35	.49	.27	1.25	(a)
22	.99	.73	1.02	.32	.42	.35	(a)	(a)
23	.99	.63	.80	.60	.35	.31	(a)	(a)
24	.96	.75	.74	.63	.20	.20	(a)	(a)
25	.92	.70	.70	.39	.26	.30	(a)	(a)
26	.94	.73	.80	.42	.26	.45	(a)	(a)
27	.93	.75	.73	2.60	.25	.72	(a)	(a)
28	.95	.75	.66	2.05	.26	.33	(a)	(a)
29	.92	.79	.65	1.31	1.22	.21	(a)	(a)
30	.91	.70	.63	1.22	.60	.33	(a)	(a)
31	.96		.54		.45	.20		(a)

a September 4 to 20, 22 to 30, no water flowing over dam. Closed for winter October 31.

Daily gage height, in feet, of mill race at Superior, Nebraska, for 1899.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1		2.98	2.84	2.54	2.15	3.05	2.86	1.15
2		3.08	2.90	2.06	1.80	2.85	2.12	1.53
3		3.03	2.93	2.65	2.18	2.38	2.79	1.10
4		2.98	3.42	2.67	2.30	1.94	2.19	1.60
5		3.02	2.61	2.50	2.34	1.86	2.00	1.20
6		2.97	2.61	2.49	2.40	2.05	2.06	1.15
7		3.04	2.15	2.59	2.42	2.87	1.41	1.28
8		2.98	3.00	2.48	2.54	2.64	1.63	1.87
9		3.04	3.10	2.41	2.01	2.78	1.56	2.79
10		2.99	3.04	2.46	2.22	2.80	1.84	1.45
11		2.92	3.01	2.69	2.38	2.07	3.62	2.15
12		2.89	3.06	3.20	2.25	2.70	3.44	1.12
13		2.90	3.10	3.22	2.94	2.90	2.88	1.70
14		2.89	3.25	3.52	2.84	3.00	3.54	1.30
15		2.77	3.19	3.35	2.80	2.78	3.88	1.78
16		2.47	3.20	3.50	2.86	2.76	3.74	3.40
17		2.97	3.12	3.38	3.08	2.95	3.79	2.30
18		2.84	3.15	3.27	3.26	2.78	3.65	3.10
19	3.13	2.82	3.36	2.56	2.95	2.68	3.53	2.74
20	2.88	2.77	3.95	3.20	2.90	2.75	3.56	2.27
21	2.84	2.83	4.88	3.21	3.08	2.35	3.94	2.75
22	2.94	2.73	3.15	2.95	3.04	2.60	3.70	1.72
23	2.93	2.51	2.97	3.35	2.93	2.48	3.50	3.01
24	2.90	2.70	2.77	3.52	2.81	2.56	3.80	1.86
25	2.81	2.75	2.73	2.43	2.60	2.60	3.43	4.02
26	2.94	2.78	2.82	3.12	2.80	2.66	3.81	3.78
27	2.90	2.83	2.78	5.69	2.70	3.00	2.17	3.63
28	2.90	2.85	2.66	4.51	2.71	3.20	2.83	3.43
29	2.95	2.80	2.83	2.45	3.80	3.10	1.20	3.92
30	2.95	2.75	2.83	2.45	2.93	2.86	1.10	3.82
31	2.96		2.73		3.43	2.90		3.33

REPUBLICAN RIVER AT JUNCTION, KANSAS.

The gaging station at this point, established by Arthur P. Davis April 26, 1895, is located at the wagon bridge at the north end of Washington street just above the mouth of the river. The gage consists of two oak timbers bolted to a post and to a cottonwood tree. One bench mark consists of a 60-penny spike driven into the base of the abutment of the bridge at an elevation of 10.67 feet on the rod; the second bench mark is the top of a stone in the base of the bridge abutment 18 feet south of the gage and at an elevation of 14.51 feet above gage datum. The right bank is high, but the left is low and may overflow in high water. The bed of the stream is sandy and liable to change. Results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 205; 1897, Nineteenth Annual Report, Part IV, page 339; 1898, Twentieth Annual Report, Part IV, page 318. The following discharge measurements were made by W. G. Russell in 1899:

April 19, gage height, 3.90 feet; discharge, 737 second-feet.
May 26, gage height, 4.20 feet; discharge, 1,029 second-feet.
June 7, gage height, 4.40 feet; discharge, 1,224 second-feet.
June 15, gage height, 3.80 feet; discharge, 936 second-feet.
October 19, gage height, 2.55 feet; discharge, 85 second-feet.

Daily gage height, in feet, of Republican River at Junction, Kansas, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.40	4.15	4.00	4.20	3.65	3.70	5.90	4.10	3.10	2.65	2.65	2.80
2	3.45	4.15	4.15	4.20	3.90	4.25	5.90	4.55	3.05	2.70	2.85	2.90
3	3.75	4.20	4.35	4.20	4.25	6.95	5.20	5.45	3.00	2.75	2.90	3.20
4	4.00	4.05	4.50	4.15	4.10	10.00	5.70	4.85	3.10	2.60	2.95	3.50
5	3.95	3.75	4.80	4.15	3.85	7.25	6.05	4.70	2.85	2.60	2.80	3.00
6	3.95	3.70	4.85	4.20	3.70	5.20	4.90	4.40	2.80	2.85	2.60	3.80
7	3.80	3.60	4.85	4.15	3.65	4.60	6.00	4.25	2.85	3.25	2.60	3.80
8	3.65	3.65	4.80	4.20	3.90	6.10	6.20	4.00	2.90	2.80	2.70	3.20
9	3.50	3.50	4.70	4.20	5.45	8.80	5.90	3.80	2.90	2.75	2.80	3.00
10	3.65	3.50	4.65	4.20	5.35	7.25	5.60	3.65	2.80	2.70	2.80	3.20
11	3.85	3.50	4.80	4.20	4.10	5.40	5.00	3.55	2.70	2.55	2.50	3.30
12	3.90	3.50	4.90	4.15	4.05	4.40	4.90	3.60	2.65	2.55	2.50	3.50
13	3.95	3.55	5.15	4.10	3.80	4.25	4.40	4.50	2.65	2.70	2.60	3.20
14	3.90	3.60	4.90	4.00	3.75	4.00	4.10	4.45	2.70	2.70	2.40	3.50
15	3.85	3.65	5.25	4.05	3.60	3.80	4.15	4.20	2.60	2.65	2.60	3.20
16	3.70	3.70	5.20	4.00	3.60	3.65	3.90	3.80	2.70	2.50	2.40	3.30
17	3.60	4.05	5.40	4.00	3.60	3.60	3.70	4.05	2.70	2.50	2.60	3.30
18	3.40	3.90	5.35	4.00	3.50	3.50	3.70	3.80	2.55	2.60	2.80	3.20
19	3.50	3.90	4.90	3.90	3.40	3.75	3.85	3.60	2.60	2.55	3.20	3.20
20	3.70	3.95	4.90	3.95	4.35	3.60	3.70	3.40	2.70	2.50	2.80	3.10
21	3.85	4.00	4.85	3.80	6.00	3.55	3.60	3.40	2.70	2.60	2.70	3.40
22	3.85	3.95	4.50	3.80	6.40	3.35	3.55	3.30	2.65	3.25	2.60	3.60
23	3.70	4.05	4.50	3.80	6.15	4.35	3.50	3.35	2.65	3.10	2.80	3.50
24	3.65	4.15	4.10	3.80	4.70	4.30	3.55	3.40	2.60	3.35	2.90	3.50
25	3.65	3.90	4.10	3.80	4.55	4.75	3.30	3.30	2.70	4.20	2.90	3.60
26	3.70	3.85	4.20	3.75	4.20	4.15	3.30	3.00	2.60	4.05	2.70	3.40
27	3.70	4.05	4.15	3.60	8.20	4.10	3.20	3.55	2.65	4.35	2.60	3.40
28	3.75	3.95	4.10	3.70	6.15	4.10	3.20	3.10	2.80	4.05	2.70	3.60
29	3.80	.....	4.10	3.70	4.55	4.80	3.20	3.10	2.90	3.55	2.90	3.90
30	3.85	.....	4.20	3.75	4.00	6.70	3.25	3.25	2.65	3.20	2.90	3.80
31	4.00	.....	4.20	.....	3.95	.....	3.35	3.05	.....	2.20	.....	3.40

SOLOMON RIVER AT NILES, KANSAS.

This river, one of the principal tributaries of Smoky Hill River, rises in western Kansas, and flows in a general easterly direction, entering the Smoky Hill River near Solomon, Kansas. The station at Niles was established May 5, 1897, and is located at a bridge one-half mile west of the town and 7 miles above the mouth of the river. The rod of the wire gage is spiked to the floor of the bridge. The bench mark is the upper of three nails driven into a cottonwood tree 18 inches in diameter, on the north side of the river and 25 feet east of the bridge, at an elevation of 24.96 feet above gage datum. The channel is straight for about 100 feet above and below the section. The current is sluggish; the right bank is high, and the left bank overflows only at very high stages. The bed of the stream is muddy. The discharge measurements may be found as follows: 1897, Nineteenth Annual Report, Part IV, page 342; 1898, Twentieth Annual Report, Part IV, page 214. The following discharge measurements were made by W. G. Russell during 1899:

April 20, gage height, 4.90 feet; discharge, 120 second-feet.
May 27, gage height, 5.10 feet; discharge, 129 second-feet.
May 29, gage height, 11.65 feet; discharge, 1,529 second-feet.
June 16, gage height, 13.60 feet; discharge, 2,270 second-feet.

Daily gage height, in feet, of Solomon River at Niles, Kansas, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	5.70	5.35	5.20	4.75	5.30	18.75	6.40	5.10	4.40	5.00	4.40
2	5.30	5.65	5.30	5.25	4.65	5.10	11.85	10.75	5.00	5.10	4.80	4.90
3	.....	5.65	5.30	5.30	5.75	8.35	8.90	10.00	5.10	4.70	4.70	4.60
4	5.20	5.65	5.30	5.25	5.35	20.00	9.65	8.25	5.10	4.45	4.80	4.40
5	5.20	5.70	5.25	5.25	4.90	23.60	8.90	6.80	4.95	4.30	4.90	4.40
6	.....	5.65	5.40	5.25	4.90	16.70	8.30	6.20	4.85	4.40	5.00	4.90
7	5.10	5.65	5.25	5.25	4.85	8.30	9.70	5.80	5.05	4.45	.....	4.70
8	5.30	5.65	5.45	5.35	5.10	16.80	8.60	5.65	4.95	4.45	4.30	4.60
9	.....	5.55	5.65	5.20	6.00	21.50	7.45	5.55	4.90	4.30	4.80	4.70
10	5.20	5.60	5.45	5.25	5.65	21.35	6.85	5.30	4.85	4.40	4.60	4.70
11	.....	5.65	5.55	5.20	6.35	15.60	6.75	5.35	4.85	4.60	4.20	4.90
12	5.20	5.45	5.45	5.30	6.55	10.00	6.60	5.30	4.70	4.40	4.80	4.70
13	.....	5.45	5.15	5.15	6.00	8.75	7.25	5.40	4.60	4.20	4.40	4.90
14	.....	5.45	5.95	5.10	5.65	7.65	10.60	5.25	4.50	4.35	4.40	4.80
15	5.30	5.50	6.50	5.00	5.15	9.80	7.65	5.25	4.60	4.35	4.50	5.00
16	.....	5.55	6.25	5.15	5.00	13.25	6.40	5.35	4.50	4.35	5.00	5.10
17	5.20	5.40	6.25	5.05	5.05	10.10	6.15	6.15	4.50	4.15	4.50	5.00
18	.....	5.45	6.95	4.95	5.00	7.15	6.40	6.55	4.50	4.15	4.40	4.90
19	6.40	5.35	5.70	5.00	4.80	6.55	6.80	6.30	4.45	4.15	4.30	5.10
20	.....	5.45	5.55	5.05	5.00	6.35	6.40	6.30	4.40	4.10	4.50	5.00
21	.....	5.40	5.50	4.85	5.10	6.15	6.40	5.90	4.45	4.20	4.40	5.10
22	6.10	5.45	5.55	4.85	5.45	5.85	6.05	5.60	4.70	4.30	4.90	4.90
23	5.75	5.35	5.25	4.90	5.30	7.15	5.85	5.50	4.55	4.30	4.50	5.00
24	5.50	5.25	5.25	4.95	5.35	8.15	5.65	5.20	4.45	4.20	4.50	4.70
25	5.25	5.40	5.35	4.80	5.20	12.45	5.65	5.15	4.45	4.55	4.70	4.80
26	5.65	5.35	5.25	4.90	5.10	12.90	5.70	5.20	4.40	4.60	4.50	4.90
27	5.50	5.45	5.15	4.85	8.50	11.85	5.40	5.10	4.55	10.25	4.70	4.70
28	5.70	5.30	5.25	4.80	14.45	11.50	5.35	5.10	4.40	8.15	4.60	4.60
29	5.75	.....	5.30	4.70	11.95	14.60	5.40	5.05	4.30	6.15	4.80	4.70
30	5.65	.....	5.25	4.80	7.15	18.60	5.55	4.85	4.45	5.30	4.70	4.60
31	5.60	.....	5.05	.....	5.80	.....	5.25	4.90	.....	5.00	.....	4.70

SALINE RIVER AT SALINA, KANSAS.

This river and the Solomon are the two principal tributaries of Smoky Hill River. They are of a similar type to the other tributaries of Kansas River, as they are sand-hill streams. Saline River joins Smoky Hill River a short distance below Salina and 9 miles, by railroad, above the mouth of Solomon River. The station, established May 4, 1897, is located at a bridge 4.5 miles northeast of Salina, near the mouth of the river. The rod of the wire gage is spiked to the floor of the bridge. Bench mark No. 1 is a nail in an elm tree 2 feet in diameter on the north side of the river and 6 feet west of the bridge. Its elevation is 22.90 feet above gage datum. Bench mark No. 2 is six nails driven into a 16-inch box-elder tree on the north side of the river and 35 feet east of the bridge. Its elevation is 22.90 feet above gage datum. The channel is straight for a little distance above and below the station. Both banks are high and not liable to overflow. The bed of the stream is sand and mud. The results of measurements may be found as follows: 1897, Nineteenth Annual Report, Part IV, page 346; 1898, Twentieth Annual Report, Part IV, page 316. The following discharge measurements for 1899 were made by W. G. Russell:

April 21, gage height, 2.90 feet; discharge, 26 second-feet.
May 27, gage height, 4.20 feet; discharge, 90 second-feet.
May 29, gage height, 12.65 feet; discharge, 1,007 second-feet.
May 30, gage height, 9.30 feet; discharge, 524 second-feet.
June 16, gage height, 8.60 feet; discharge, 560 second-feet.

Daily gage height, in feet, of Saline River at Salina, Kansas, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	.....	.....	3.35	2.90	4.55	8.95	4.25	3.55	3.20	4.80	3.60
2	3.90	3.30	3.50	3.35	2.90	4.00	7.85	4.35	3.90	3.05	4.90	3.40
3	.....	.....	.....	3.35	3.70	9.95	6.95	4.55	3.75	3.10	4.10	3.60
4	3.80	3.20	.....	3.25	3.70	23.95	6.50	4.50	3.60	3.30	3.90	3.80
5	.....	.....	4.05	3.25	2.95	21.30	6.25	4.35	3.50	3.25	3.70	3.80
6	.....	.....	3.95	3.20	2.90	17.50	6.05	4.25	3.35	3.10	3.70	3.60
7	3.40	3.20	4.00	3.45	3.10	10.50	6.65	4.00	3.30	3.05	3.60	3.60
8	.....	.....	3.75	3.40	3.05	11.40	7.20	3.90	3.30	3.15	3.50	3.60
9	3.60	3.20	3.50	3.35	3.00	21.70	7.05	3.85	3.35	3.00	3.50	3.60
10	.....	3.30	3.80	3.35	2.80	27.15	6.15	3.80	3.35	3.00	3.50	3.60
11	3.70	3.30	3.75	3.30	2.70	23.50	7.55	3.80	3.25	3.00	3.50	3.80
12	.....	.....	3.65	3.35	2.60	21.20	10.05	3.80	3.20	3.20	3.40	3.60
13	.....	.....	4.10	3.10	2.70	15.10	8.60	4.15	3.30	3.10	3.60	3.60
14	3.80	3.10	3.70	3.30	3.00	8.40	6.45	4.10	3.25	3.05	3.60	3.70
15	.....	.....	3.70	3.25	2.95	7.25	6.15	3.95	3.30	3.05	3.50	3.80
16	.....	3.20	3.95	3.15	2.85	8.85	6.00	3.80	3.40	3.15	3.50	3.60
17	3.50	.....	3.75	3.15	2.90	13.45	6.20	3.75	3.55	3.05	3.60	3.90
18	.....	3.10	3.65	2.95	2.85	9.95	5.50	4.05	3.55	3.00	3.50	3.90
19	3.50	.....	3.65	3.00	2.75	7.25	5.30	4.05	3.35	3.10	3.60	3.80
20	.....	.....	3.35	3.00	2.85	5.80	5.15	3.85	3.35	3.05	3.50	3.70
21	3.70	3.30	3.35	2.80	2.75	5.35	4.95	3.70	3.35	3.10	3.60	3.60
22	.....	.....	3.45	3.00	4.35	5.10	4.85	3.65	3.25	3.20	3.60	3.70
23	3.20	3.40	3.15	3.10	11.35	5.40	4.65	3.55	3.25	3.10	3.60	3.60
24	.....	.....	3.25	3.10	9.40	7.50	4.60	3.60	3.35	3.05	3.70	3.40
25	.....	3.40	3.30	3.05	5.70	12.35	4.55	3.55	3.20	3.45	3.60	3.60
26	3.30	.....	3.30	3.10	4.75	15.30	4.45	3.60	3.15	4.00	3.60	3.80
27	.....	.....	3.35	3.05	4.20	17.70	4.35	3.55	3.25	3.65	3.70	3.60
28	3.30	3.90	3.10	2.90	6.85	19.65	4.35	3.50	3.25	3.35	3.50	3.60
29	.....	.....	3.15	2.85	12.60	20.05	4.30	3.30	3.30	7.30	3.60	3.60
30	.....	.....	3.20	2.95	8.15	14.25	4.35	3.25	3.25	6.60	3.80	3.60
31	3.30	.....	3.50	.....	5.20	.....	4.35	3.25	.....	5.50	.....	3.50

SMOKY HILL RIVER AT ELLSWORTH, KANSAS.

This river rises in eastern Colorado, and flows easterly, joining the Republican River at Junction to form the Kansas River. The gaging station, established April 17, 1895, is located at the highway bridge on Douglass avenue, Ellsworth, Kansas. The gage is an inclined ash timber spiked to a post driven in the bed of the river and bolted to an iron post on the bridge pier. The bench mark is a nail driven in the base of a large box-elder tree near the southeast corner of the bridge, 90 feet from the gage, and its elevation is 13.07 feet above the zero of the gage. A slope gage is spiked to the Saint Louis and San Francisco Railroad bridge 2,536 feet upstream, and is referred to the same datum. The channel is nearly straight above and below the gage, and the bed is sandy and shifting. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 214; 1897, Nineteenth Annual Report, Part IV, page 347; 1898, Twentieth Annual Report, Part IV, page 315. Measurements for 1899 were made by W. G. Russell, as follows:

March 20, gage height, 1.25 feet; discharge, 35 second-feet.
June 6, gage height, 2.07 feet; discharge, 184 second-feet.
June 26, gage height, 1.95 feet; discharge, 189 second-feet.
July 7, gage height, 4.75 feet; discharge, 1,675 second-feet.
July 8, gage height, 13 feet; discharge, 10,986 second-feet.
July 8, gage height, 10.95 feet; discharge, 7,348 second-feet.

Daily gage height, in feet, of Smoky Hill River at Ellsworth, Kansas, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	.....	1.20	1.17	0.98	0.88	1.58	2.25	1.40	1.13	1.30	1.20
2	.....	.....	1.40	1.17	.95	.90	1.38	2.13	1.33	1.10	1.30	1.20
3	1.40	.....	1.50	1.10	.90	5.00	2.33	2.05	1.33	1.30	1.25	1.15
4	.....	1.30	1.45	1.13	.93	3.25	2.33	1.96	1.23	1.10	1.25	1.15
5	1.40	.....	1.30	1.17	.95	1.98	2.00	1.95	1.30	1.10	1.25	1.15
6	.....	.....	1.20	1.23	.98	3.20	1.83	1.88	1.28	1.30	1.20	1.10
7	1.50	1.30	1.30	1.20	.98	4.10	8.60	1.80	1.20	1.50	1.20	1.10
8	.....	.....	1.20	1.17	1.00	3.00	11.35	1.73	1.28	1.50	1.25	1.15
9	.....	.....	1.38	1.15	.95	7.70	6.00	1.73	1.38	1.30	1.25	1.15
10	1.50	.....	1.35	1.17	.93	5.70	5.10	1.73	1.50	1.30	1.25	1.20
11	.....	1.30	1.30	1.17	.93	3.45	4.58	1.68	1.38	1.30	1.25	1.20
12	1.50	.....	1.35	1.17	.98	2.80	3.80	1.60	1.35	1.10	1.20	1.15
13	1.40	1.50	1.40	1.23	1.00	2.20	3.33	1.95	1.50	1.10	1.20	1.15
14	1.05	.....	1.43	1.17	.95	2.00	2.85	1.78	1.50	1.50	1.20	1.20
15	1.20	1.50	1.45	1.20	.98	1.90	2.70	1.68	1.48	1.50	1.15	1.20
16	1.30	.....	1.35	1.17	.95	1.75	2.60	1.63	1.45	1.10	1.15	1.20
17	1.10	1.50	1.38	1.10	.90	1.60	2.70	1.60	1.48	1.10	1.15	1.25
18	1.30	.....	1.30	1.08	.95	1.60	2.40	1.55	1.40	1.50	1.10	(a)
19	1.40	1.50	1.28	1.08	.90	1.53	2.28	1.50	1.33	1.50	1.15	1.25
20	1.25	1.50	1.28	1.08	1.00	1.50	2.23	1.43	1.30	1.05	1.15	(a)
21	1.35	1.55	1.23	1.08	.95	1.45	2.18	1.40	1.28	1.05	1.20	(a)
22	1.35	1.45	1.23	1.08	.93	1.40	2.23	1.40	1.23	1.25	1.25	1.20
23	1.35	1.45	1.13	1.05	.95	3.15	2.23	1.33	1.23	1.25	1.20	1.20
24	1.20	1.40	1.17	1.03	1.03	2.85	2.20	1.30	1.20	1.30	1.20	1.20
25	1.15	1.40	1.15	1.03	1.10	2.25	2.13	1.35	1.20	1.40	1.25	1.15
26	1.30	1.40	1.17	1.03	1.13	2.15	2.10	3.85	1.15	1.75	1.25	1.20
27	1.20	1.40	1.15	1.00	1.08	1.90	2.05	2.75	1.15	1.58	1.20	1.20
28	1.30	1.45	1.15	1.00	.98	2.00	2.35	2.35	1.13	1.50	1.20	(a)
29	1.30	.....	1.10	1.00	.90	1.95	2.90	1.65	1.10	1.45	1.20	1.20
30	1.30	.....	1.20	.98	.93	1.80	2.45	1.50	1.10	1.45	1.20	1.25
31	.....	.....	1.17	.....	.88	.....	2.30	1.43	.....	1.35	.....	1.20

a Frozen.

BLUE RIVER AT MANHATTAN, KANSAS.

This stream is one of the principal tributaries of Kansas River, and drains a part of southeastern Nebraska and northeastern Kansas. It enters Kansas River at Manhattan. Its tributaries extend almost to the Platte River. The drainage basin receives a copious rainfall, and therefore the run-off is considerably larger than from the more western tributaries of Kansas River. The gaging station, established April 12, 1895, is at the county bridge 4 miles north of Manhattan. The gage rod consists of three sections, the lower being an ash stick driven into the bottom of the river and bolted to an overhanging cottonwood tree 30 feet east of the bridge. The other two sections of the rod are bolted to the south bridge pier. The bench mark is a cross cut in the capstone of the south bridge pier immediately above the upper gage, and is 32.135 feet above gage datum. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 218; 1897, Nineteenth Annual Report, Part IV, page 348; 1898, Twentieth Annual Report, Part IV, page 319. The following discharge measurements were made by W. G. Russell during 1899:

April 20, gage height, 4.60 feet; discharge, 767 second-feet.
May 23, gage height, 13.70 feet; discharge, 8,952 second-feet.
June 8, gage height, 16.60 feet; discharge, 20,237 second-feet.
June 9, gage height, 18.30 feet; discharge, 19,529 second-feet.
June 10, gage height, 15.60 feet; discharge, 13,616 second-feet.
October 18, gage height, 3.70 feet; discharge, 366 second-feet.

Daily gage height, in feet, of Blue River at Manhattan, Kansas, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.50	4.80	4.65	4.95	4.88	5.70	6.85	7.05	4.20	3.80	4.25	4.00
2	4.40	4.70	4.65	4.85	5.45	5.95	6.25	5.90	4.15	3.80	4.25	3.95
3	4.40	4.60	4.95	4.75	5.35	12.85	6.85	5.25	4.30	3.80	4.15	4.05
4	4.40	4.70	5.75	4.85	6.05	23.00	6.35	4.90	4.25	3.80	4.05	4.10
5	4.40	4.85	5.80	4.90	5.90	12.65	5.85	5.15	4.15	3.80	4.00	3.95
6	4.50	4.90	5.70	5.15	5.10	8.40	8.35	6.75	4.00	3.80	4.00	4.00
7	4.45	4.80	5.60	5.45	4.75	7.60	10.65	6.00	4.05	3.80	4.15	3.95
8	4.45	4.75	6.00	5.65	5.10	13.95	14.25	5.20	4.05	3.85	4.10	3.90
9	4.45	4.70	6.05	5.65	5.95	18.25	12.90	5.00	4.20	3.80	4.10	4.00
10	4.45	4.80	6.10	5.45	10.55	15.80	10.60	4.70	4.30	3.75	4.10	4.15
11	4.60	4.85	7.40	5.30	10.25	11.25	9.00	4.70	4.10	3.85	4.10	4.20
12	4.75	4.90	7.35	5.15	6.40	8.75	8.35	4.65	4.05	3.80	4.10	4.30
13	4.75	4.80	6.40	5.00	5.80	8.05	7.40	7.00	3.90	3.80	4.05	3.95
14	4.65	4.80	6.00	5.00	5.40	7.20	7.25	11.45	3.95	3.80	4.05	3.75
15	4.55	4.90	9.00	4.95	5.00	6.83	6.55	9.25	3.95	3.80	3.95	4.55
16	4.50	4.60	12.20	4.85	5.00	6.50	6.60	9.20	4.00	3.95	4.05	4.30
17	4.50	4.65	9.95	4.75	5.05	6.60	6.60	8.15	4.00	3.80	4.20	4.45
18	4.50	4.60	8.35	4.75	4.80	6.75	6.10	7.00	3.75	3.80	4.20	4.20
19	4.40	4.65	7.25	4.70	4.30	6.90	5.75	6.10	3.75	3.80	4.20	4.10
20	4.40	4.75	6.60	4.58	13.10	6.95	5.60	5.60	3.90	3.80	4.15	3.90
21	4.45	4.70	6.25	4.53	21.55	6.70	5.50	5.30	3.95	3.75	4.00	4.10
22	4.50	4.75	6.15	4.48	22.85	6.55	5.25	4.90	3.90	3.95	4.00	4.10
23	4.50	4.90	5.90	4.50	13.50	6.25	5.15	4.80	3.90	3.45	3.95	4.15
24	4.50	5.25	5.55	4.50	9.40	6.15	5.10	4.80	3.90	3.80	3.90	4.05
25	4.40	5.20	5.40	4.50	8.90	6.35	4.95	4.50	3.90	3.90	4.05	4.15
26	4.40	5.20	5.25	4.43	9.10	6.40	4.90	4.20	3.80	7.05	4.10	3.95
27	4.50	5.10	5.25	4.45	9.65	6.30	4.85	3.50	3.90	6.80	4.05	3.90
28	4.50	4.95	5.20	5.63	7.25	7.35	5.05	4.50	3.80	5.65	4.05	3.85
29	4.80	.....	5.05	5.70	6.45	6.45	6.90	4.45	3.80	4.95	4.05	3.70
30	4.85	.....	5.05	5.20	6.00	6.45	12.00	4.35	3.80	4.70	4.05	3.70
31	4.90	.....	5.00	.....	6.10	.....	8.25	4.40	.....	4.40	.....	4.05

KANSAS RIVER AT LECOMPTON, KANSAS.

This river, formed by the junction of Republican and Smoky Hill rivers at Junction, Kansas, flows in a general easterly direction into Missouri River at Kansas City. The gaging station at Lecompton was established April 16, 1899, and is located at the new carriage bridge recently built across the river.

The following discharge measurements were made by E. C. Murphy and W. G. Russell during 1899:

Measurements of Kansas River at Lecompton, Kansas.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Sec.-feet.*	1899.	*Feet.*	*Sec.-feet.*
Apr. 7	3.40	2,935	June 5	9.90	21,762
Apr. 15	3.35	2,747	June 12	6.60	11,549
Apr. 21	3.15	2,251	June 16	3.52	4,326
Apr. 29	5.90	8,744	July 17	6.30	10,500
May 11	6.35	10,859	July 28	3.95	3,349
May 25	11.20	34,213	Oct. 10	2.00	1,889

Daily gage height, in feet, of Kansas River at Lecompton, Kansas, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	3.40	4.50	5.45	5.55	2.60	2.00	2.90	2.10
2	.....	3.35	4.15	6.25	4.45	2.60	2.00	2.80	2.10
3	.....	3.20	4.00	6.20	4.15	2.60	2.00	2.70	2.10
4	.....	3.20	7.10	6.00	3.95	2.60	2.00	2.60	2.10
5	.....	3.20	9.50	5.90	3.85	2.50	2.00	2.50	2.10
6	.....	3.20	8.90	5.75	4.85	2.50	2.00	2.50	2.05
7	.....	3.40	7.90	9.05	4.50	2.40	2.00	2.40	2.00
8	.....	3.40	7.25	11.00	4.40	2.40	2.00	2.40	2.00
9	.....	3.40	9.25	8.85	4.30	2.30	2.00	2.40	2.00
10	.....	3.55	10.00	8.50	3.90	2.30	2.00	2.30	2.00
11	.....	5.80	9.00	7.80	3.50	2.30	2.00	2.30	2.15
12	.....	6.15	7.80	6.70	3.50	2.30	2.00	2.30	2.25
13	.....	5.25	7.30	6.20	3.50	2.30	1.90	2.30	2.45
14	.....	4.45	6.90	5.90	4.00	2.30	1.90	2.30	2.65
15	.....	3.95	6.65	6.40	5.40	2.20	1.90	2.30	2.90
16	3.50	3.65	6.55	6.60	5.50	2.20	1.90	2.30	3.00
17	3.40	3.50	6.10	6.25	5.10	2.20	1.90	2.30	3.00
18	3.30	3.35	5.30	5.85	4.75	2.20	1.90	2.20	2.90
19	3.20	3.30	5.00	5.30	4.40	2.20	1.90	2.20	2.90
20	4.70	3.35	4.95	4.80	4.15	2.20	1.90	2.20	2.80
21	3.40	8.00	4.85	4.45	3.80	2.20	1.90	2.20	2.70
22	3.40	(a)	4.65	4.25	3.55	2.10	1.90	2.20	2.65
23	3.40	(a)	4.50	4.05	3.45	2.10	1.90	2.20	2.60
24	3.40	7.50	4.50	3.85	3.25	2.10	1.90	2.20	2.60
25	3.30	6.15	4.80	3.70	3.05	2.10	1.90	2.20	2.60
26	3.20	5.65	4.90	3.60	2.90	2.10	1.90	2.20	2.50
27	3.20	5.10	5.05	3.60	2.90	2.00	2.05	2.20	2.50
28	3.20	5.90	5.35	3.50	2.90	2.00	2.45	2.10	2.45
29	3.20	6.45	5.55	3.45	2.80	2.00	2.75	2.10	2.40
30	3.20	5.10	5.70	5.15	2.80	2.00	3.00	2.10	2.40
31	.....	4.75	.....	5.30	2.70	.....	3.00	.....	2.40

a Water over gage.

KANSAS RIVER AT LAWRENCE, KANSAS.

The station at this point, 11 miles below the Lecompton station, was established in July, 1895, and is located at the wagon bridge at Lawrence, Kansas. The gage was fastened to the south pier of the bridge, about 50 feet up the river from the crest of the dam. Owing to the impossibility of accurately rating this station, no measurements of discharge were made here during 1899, but gage readings were maintained until November 4, when the station was discontinued. The Lecompton station was established to take the place of this one. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 220; 1897, Nineteenth Annual Report, Part IV, page 350; 1898, Twentieth Annual Report, Part IV, page 322.

Daily gage height, in feet, of Kansas River at Lawrence, Kansas, for 1899.

[Sign — indicates that water is below zero of gage.]

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	0.50	—1.75	.80	1.20	1.20	2.00	2.35	2.85	0.60	0.10	0.80
2	.60	— .50	1.10	1.20	1.00	1.90	2.70	1.95	.60	.15	.75
3	.60	.00	.90	1.20	1.00	2.10	2.95	1.65	.60	.20	.75
4	.80	.10	1.05	1.20	.85	2.70	2.80	1.55	.60	.20	.65
5	.90	.00	2.00	1.25	.85	5.60	2.65	1.40	.60	.20	.....
6	.70	.40	1.80	1.35	.90	5.50	2.55	1.50	.55	.20	.....
7	.65	— .70	.70	1.60	1.20	3.75	4.50	1.80	.50	.20	.....
8	.80	— .60	.90	1.60	1.10	3.50	6.55	1.90	.50	.20	.....
9	.60	.00	1.05	1.80	1.00	4.60	4.80	1.50	.50	.10	.....
10	.50	— .50	1.30	1.75	1.20	6.20	4.50	1.40	.50	.00	.....
11	.45	— .80	1.30	1.60	2.90	6.30	3.55	1.30	.50	.00	.....
12	.50	— .20	2.80	1.45	2.80	5.40	3.00	1.25	.50	.00	.....
13	.50	— .60	2.90	1.40	2.60	4.10	2.55	1.10	.50	—.10	.....
14	.50	—1.20	2.80	1.25	1.80	3.80	2.65	1.35	.40	—.20	.....
15	.50	—1.20	2.60	1.10	1.45	3.50	2.75	1.90	.40	—.20	.....
16	.45	—1.40	3.70	1.00	1.20	3.10	3.00	2.65	.35	—.30	.....
17	.40	— .15	3.60	1.00	1.00	2.80	3.00	2.25	.40	—.20	.....
18	.40	.00	3.50	.90	1.00	2.15	2.70	2.05	.40	—.20	.....
19	.40	.50	2.80	.80	1.00	2.00	2.25	1.70	.35	—.20	.....
20	.55	.50	2.10	2.70	1.00	2.00	1.95	1.50	.30	—.20	.....
21	.75	.55	1.80	1.35	3.40	1.95	1.80	1.35	.30	—.20	.....
22	.80	.35	1.80	1.00	5.65	1.85	1.60	1.15	.30	—.30	.....
23	.75	.00	1.55	1.00	5.80	1.70	1.60	1.00	.30	—.30	.....
24	.75	— .20	1.50	1.00	4.80	1.90	1.50	1.00	.30	—.30	.....
25	.70	.00	1.40	1.00	3.10	2.00	1.40	.85	.30	—.35	.....
26	.80	.50	1.40	1.00	2.50	2.00	1.40	.85	.20	—.35	.....
27	.65	.70	1.40	1.00	2.10	2.10	1.25	.80	.10	—.30	.....
28	.35	.80	1.35	1.00	2.70	2.40	1.15	.80	.05	—.35	.....
29	.60	.....	1.20	1.00	3.10	2.40	1.10	.80	.00	+.80	.....
30	.40	.....	1.20	1.40	2.60	2.40	1.80	.75	.00	.85	.....
31	.60	.....	1.20	.....	1.90	.....	2.35	.65	.....	.85	.....

Station discontinued October 31.

ARKANSAS RIVER.

The source of this river is in the vicinity of Tennessee Pass, in the central portion of Colorado. It flows southerly for about 70 miles, then easterly for 50 miles to Canyon, receiving a number of tributaries from the mountainous area on either side, which tends to increase the discharge of the river. At Canyon it suddenly emerges from the Rocky Mountain front and thence flows in an easterly direction, traversing the Great Plains of eastern Colorado, in which section most of the water is diverted for irrigation. After crossing the Kansas line it continues eastward for about 200 miles until the center of the State is reached, when it suddenly bends to the southward and passes into Indian Territory, and from thence into the State of Arkansas, finally entering the Mississippi River about 25 miles above Greenville, Mississippi. Throughout the mountainous area above Canyon the discharge increases, but as soon as the river emerges onto the Great Plains the water is gradually diverted by means of canals, so that by the time the Kansas line is reached the river is usually dry during the summer stages. In its mountainous course the river makes a descent from 10,000 feet at Leadville to 5,300 feet at Canyon, a distance of 120 miles.

During the last year two notable examples of engineering construction have been practically completed in this basin. The first one is the Twin Lakes reservoir, in which a dam 30 feet in height, of solid

masonry, has been completed in a cut below the outlet of the lower lake of Twin Lakes, which is one source of supply of the Arkansas. This is designed to store water for a canal 130 miles below, which heads a few miles below Pueblo. The ditch has been cleaned out during the last season, and it is stated that $2,000,000 are being spent on a sugar-beet factory receiving water from it.

Twelve miles north of Lamar, Colorado, are a series of depressions in the plains, separated by ridges. Five of these have been connected by ditches, making the continuous reservoir system of The Great Plains Water Company. Their total available capacity is 194,562 acre-feet. It is the intention to fill them from the Arkansas River during the winter and high-water seasons by means of a supply ditch, which is now completed. This ditch is about 90 miles long and heads immediately above La Junta. Its capacity at the head is 2,000 second-feet. A number of gaging stations have been maintained in this drainage basin, and they are described in order down stream:

LAKE CREEK AT TWIN LAKES, COLORADO.

This creek enters the Arkansas a short distance above Granite, Colorado. The station was established June 21, 1899, by Mr. O. O. McReynolds, chief engineer of the Colorado Land and Water Company, which has been at work on the reservoir of Twin Lakes during the last year. It was at first contemplated that measurements should be made showing the discharge into the upper lake, between the two lakes, and below the lower lake, but owing to difficulties encountered only a few measurements were made at the two upper points. On July 17 the discharge entering the upper lake, at a gage height of 2.80 feet, was found to be 273 second-feet; on October 12, at the same point, with a gage height of 1.9 feet, the discharge was 27 second-feet. Three measurements of discharge were made at a point between the two lakes: June 21, at a gage height of 3.60 feet, the discharge was found to be 1,007 second-feet; July 17, at a gage height of 1.90 feet, the discharge was 374 second-feet; October 12, gage height, 1.4 feet; discharge, 42 second-feet. A number of discharge measurements at the lower station were made, sufficient for the construction of a rating table covering the period from June 21 to July 20, but after that date the surface of the lakes was raised and lowered periodically through the operations of a placer company which had constructed a dam below the lower lake. The following measurements of discharge were made by A. L. Fellows and O. O. McReynolds during 1899:

June 21, gage height, 3.80 feet; discharge, 1,208 second-feet.
June 27, gage height, 3.20 feet; discharge, 696 second-feet.
July 17, gage height, 2.55 feet; discharge, 391 second-feet.
July 24, gage height, 2.50 feet; discharge, 344 second-feet.
August 14, gage height, 2.50 feet; discharge, 183 second-feet.
October 13, gage height ———; discharge, 23 second-feet.

Daily gage height, in feet, of Lake Creek at Twin Lakes, Colorado, for 1899.

Day.	June.	July.	Aug.	Sept.	Day.	June.	July.	Aug.	Sept.	Day.	June.	July.	Aug.	Sept.
1	.....	3.10	2.72	2.15	12	.....	2.65	2.60	.....	23	3.65	2.50	2.30	.....
2	.....	3.15	2.72	2.10	13	.....	2.75	2.55	.....	24	3.50	2.52	2.30	.....
3	.....	3.10	2.78	2.10	14	.....	2.65	2.50	.....	25	3.40	2.50	2.25	.....
4	.....	3.05	2.88	2.10	15	.....	2.55	2.48	.....	26	3.30	2.45	2.25	.....
5	.....	2.95	2.95	2.05	16	.....	2.50	2.45	.....	27	3.20	2.48	2.22	.....
6	.....	2.95	2.98	2.05	17	.....	2.50	2.45	.....	28	3.10	2.55	2.20	.....
7	.....	2.90	2.90	2.05	18	.....	2.50	2.45	.....	29	3.10	2.65	2.15	.....
8	.....	2.85	2.88	2.05	19	.....	2.50	2.40	.....	30	3.10	2.70	2.15	.....
9	.....	2.80	2.85	2.00	20	.....	2.50	2.40	.....	31	.....	2.70	2.15	.....
10	.....	2.75	2.75	2.00	21	3.80	2.55	2.40	.....					
11	.....	2.70	2.65	2.00	22	3.70	2.55	2.35	.....					

ARKANSAS RIVER AT GRANITE, COLORADO.

This station is located at the wagon bridge, 250 feet from the railroad station at Granite, Colorado. The gage is a vertical 2 by 6 inch plank spiked to the upper end of the center pier of the bridge. The banks are low and liable to overflow; the bed is rocky, and the current swift. It will be impossible to construct a rating table for this station from the measurements obtained in 1899. The results of measurements may be found as follows: 1897, Nineteenth Annual Report, Part IV, page 354; 1898, Twentieth Annual Report, Part IV, page 330. The following discharge measurements were made by A. L. Fellows during 1899:

May 25, gage height, 5 feet; discharge, 1,476 second-feet.
July 15, gage height, 2.80 feet; discharge, 1,178 second-feet.
October 14, gage height, 1.60 feet; discharge, 180 second-feet.

Daily gage height, in feet, of Arkansas River at Granite, Colorado, for 1899.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.
1	.....	3.15	3.90	5.80	3.90	2.40	2.00
2	.....	3.25	3.80	5.75	3.90	2.40	2.00
3	.....	3.25	3.80	5.25	3.90	2.40	2.00
4	.....	2.25	3.80	4.80	3.80	2.60	2.00
5	.....	3.20	3.80	4.50	3.50	2.60	2.00
6	.....	3.20	3.80	4.60	3.50	2.60	2.00
7	.....	3.20	3.90	4.85	3.45	2.60	2.00
8	.....	3.15	3.95	5.00	3.40	2.60	2.00
9	.....	3.25	4.05	5.00	3.40	2.60	2.00
10	.....	3.35	4.20	5.00	3.40	2.40	2.00
11	.....	3.45	4.35	5.40	3.35	2.40	.....
12	.....	3.45	4.60	6.70	3.30	2.40	.....
13	.....	3.50	4.95	6.95	3.00	2.40	.....
14	.....	3.50	5.40	6.90	3.00	2.40	.....
15	.....	3.50	5.80	6.40	2.80	2.40	.....
16	.....	3.50	5.80	6.00	2.80	2.00	.....
17	.....	3.50	5.80	5.85	2.80	2.00	.....
18	.....	3.50	5.90	5.75	2.80	2.00	.....
19	.....	3.50	5.90	5.85	2.80	2.00	.....
20	.....	3.50	5.75	5.85	2.80	2.00	.....
21	.....	3.50	5.65	5.70	2.80	2.00	.....
22	.....	3.55	5.00	5.65	2.80	2.00	.....
23	3.30	3.65	4.80	5.00	2.80	2.00	.....
24	3.15	3.65	4.95	4.85	2.80	2.00	.....
25	3.20	3.75	5.00	4.60	2.80	2.00	.....
26	3.25	3.95	5.35	4.40	2.80	2.00	.....
27	3.25	4.00	5.65	4.00	2.60	2.00	.....
28	3.25	4.00	5.75	3.90	2.60	2.00	.....
29	3.20	3.90	5.60	3.90	2.60	2.00	.....
30	3.10	3.90	5.90	3.90	2.60	2.00	.....
31	3.15	.....	6.00	.....	2.60	2.00	.....

ARKANSAS RIVER AT SALIDA, COLORADO.

This station was established April 11, 1895, and is located at the suspension bridge at Salida, Colorado. The gage consists of a vertical timber bolted to the abutment of the bridge; the banks are high and do not overflow; the bed of the stream consists of sand and gravel. Large bowlders interfere to a considerable extent with the accuracy of the results. Results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 224; 1897, Nineteenth Annual Report, Part IV, page 355; 1898, Twentieth Annual Report, Part IV, page 331. The following discharge measurements were made by A. L. Fellows during 1899:

April 26, gage height, 1.72 feet; discharge, 686 second-feet.
May 25, gage height, 3.10 feet; discharge, 1,999 second-feet.
July 14, gage height, 2.40 feet; discharge, 1,801 second-feet.
November 8, gage height, 0.80 feet; disharge, 317 second-feet.

Daily gage height, in feet, of Arkansas River at Salida, Colorado, for 1899.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.
1	.....	0.80	1.30	3.25	3.20	1.60	0.80
2	.....	.80	1.35	3.35	3.20	1.60	.80
3	.....	.80	1.25	3.10	3.20	1.70	.80
4	.....	.80	1.20	2.85	3.20	2.40	.70
5	.....	.85	1.25	2.65	3.10	2.10	.70
6	.....	.80	1.40	2.60	3.20	2.15	.60
7	.....	.80	1 50	2.85	3.05	1.85	.60
8	.....	.80	1.65	2.90	2.90	1.65	.55
9	.....	.85	1.95	3.05	2.50	1.45	.50
10	.....	.95	2.05	3.20	2.45	1.40	.50
11	.....	1.00	2.10	3.50	2.40	1.35	.50
12	.....	1.02	2.25	3.60	2.35	1.15	.50
13	.....	1.10	2.45	3.70	2.65	1.20	.75
14	.....	1.00	2.70	4.60	2.35	1.20	.90
15	.....	1.05	2.85	4.30	2.45	1.20	1.00
16	.....	1.20	2.90	4.85	2.40	1.20	1.00
17	.....	1.20	2.90	5.00	2.80	1.10	.80
18	.....	1.10	2.95	4.85	2.50	1.10	.70
19	.....	1.15	3.00	4.95	2.40	1.05	.65
20	.....	.95	3.00	5.10	2.30	1.00	.55
21	.....	.90	2.80	5.00	2.00	1.00	.50
22	0.80	.95	2.60	4.50	1.85	.90	.50
23	.80	1.10	2.45	4.20	1.80	.80	.50
24	.80	1.20	2.50	4.20	1.85	.80	.50
25	.80	1.30	2.75	4.10	1.65	.80	.50
26	.90	1.55	2.95	3.85	1.60	.70	.50
27	.70	1.60	3.10	3.50	1.65	.70	.40
28	.70	1.65	3.10	3.20	1.55	.70	.40
29	.70	1.50	3.10	3.20	1.40	.70	.40
30	.70	1.40	3.20	3.20	1.50	.70	.40
31	.70	.....	3.25	.....	1.60	.90	.....

Closed for the winter September 30.

ARKANSAS RIVER AT CANYON, COLORADO.

This station, established in 1889, is located at the Hot Springs Hotel, 1½ miles west of Canyon and about 500 yards below the mouth of Grape Creek. The gage rod is placed on the left bank of the river, just below the suspension foot bridge, and consists of an inclined 4 by 4 inch timber bolted to posts set in the ground. The station is an important one, as it is located at the mouth of the canyon and

above most of the canal diversions. The only two ditches taking water above the gaging station are the North and South Side ditches, which were each measured three times during 1899, as follows: On April 27, August 18, and November 7. North Side ditch, on the first date, was carrying 55 second-feet, and the South Side ditch 48 second-feet; on the second date North Side ditch was discharging 35 second-feet and the South Side ditch 43 second-feet; at the third measurement of discharge the North Side ditch showed 28 second-feet and the South Side 36 second-feet. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 226; 1897, Nineteenth Annual Report, Part IV, page 356; 1898, Twentieth Annual Report, Part IV, page 331. The discharge measurements were made by A. L. Fellows for 1899, as follows:

April 27, gage height, 3.20 feet; discharge, 611 second-feet.
May 26, gage height, 4.55 feet; discharge, 2,189 second-feet.
July 7, gage height, 4.50 feet; discharge, 2,651 second-feet.
August 18, gage height, 2.90 feet; discharge, 553 second-feet.
November 7, gage height, 2.55 feet; discharge, 306 second-feet.

Daily gage height, in feet, of Arkansas River at Canyon, Colorado, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	.....	.....	2.80	3.25	5.00	5.00	3.60	2.60	.....	.....	.....
2	.....	.....	.....	2.80	3.10	5.05	5.30	3.50	2.50	.....	.....	a2.70
3	.....	.....	.....	2.80	3.05	5.00	5.00	3.50	2.50	.....	.....	.....
4	.....	2.60	3.40	2.80	2.90	4.75	4.85	4.10	2.50	a2.20	a2.60	.....
5	.....	.....	.....	2.80	2.90	4.50	4.75	4.45	2.40	.....	.....	.....
6	2.60	.....	.....	2.80	2.90	4.45	4.60	3.65	2.40	.....	.....	.....
7	.....	.....	.....	2.70	3.00	4.65	4.55	3.50	2.30	.....	.....	.....
8	.....	.....	.....	2.70	3.15	4.70	4.40	3.50	2.30	.....	.....	.....
9	.....	.....	.....	2.70	3.35	4.75	4.30	3.40	2.30	.....	.....	a2.70
10	.....	.....	.....	2.75	3.55	4.85	4.20	3.30	2.30	.....	.....	.....
11	.....	2.50	3.00	2.80	3.65	5.05	4.10	3.10	2.20	a2.40	a2.80	.....
12	.....	.....	.....	3.00	3.90	5.45	4.05	3.00	2.20	.....	.....	.....
13	.....	.....	.....	3.00	4.25	5.85	4.45	3.00	2.20	.....	.....	.....
14	2.60	.....	.....	3.05	4.50	6.00	4.25	3.00	2.20	.....	.....	.....
15	.....	.....	.....	3.00	4.70	5.95	4.25	2.90	2.30	.....	.....	.....
16	.....	.....	.....	3.05	4.80	5.95	4.40	2.80	2.30	.....	.....	a2.50
17	.....	.....	.....	3.00	4.85	5.95	4.10	2.95	2.60	.....	.....	.....
18	.....	2.10	2.70	3.00	4.65	6.05	4.05	2.90	2.50	.....	a2.90	.....
19	.....	.....	.....	2.95	4.75	6.10	4.50	2.85	2.40	.....	.....	.....
20	.....	.....	.....	3.00	4.80	6.10	4.10	2.80	2.40	a2.40	.....	.....
21	2.60	.....	.....	2.75	4.65	6.05	3.90	2.70	2.30	.....	.....	.....
22	.....	.....	.....	2.70	4.40	5.95	3.80	2.70	2.30	.....	.....	.....
23	.....	.....	.....	2.75	4.20	5.75	3.70	2.60	2.30	.....	.....	a2.50
24	.....	.....	.....	2.90	4.15	5.60	3.70	2.60	2.30	.....	.....	.....
25	.....	3.00	2.70	3.05	4.50	5.50	3.60	2.50	2.30	.....	a3.00	.....
26	.....	.....	.....	3.20	4.60	5.30	3.50	2.50	2.30	.....	.....	.....
27	.....	.....	.....	3.30	4.80	5.25	3.50	2.50	2.20	.....	.....	.....
28	2.60	.....	.....	3.35	4.80	5.00	3.60	2.50	2.20	a2.50	.....	.....
29	.....	.....	.....	3.40	4.80	5.05	3.55	2.50	2.20	.....	.....	.....
30	.....	.....	.....	3.25	4.90	4.95	3.65	2.40	2.20	.....	.....	a2.80
31	.....	.....	.....	.....	5.00	.....	3.60	2.50	.....	.....	.....	.....

a Average for week.

ARKANSAS RIVER AT PUEBLO, COLORADO.

This station was established in September, 1894, and is at present located at Main street bridge in the city of Pueblo. The gage is a 2 by 6 inch plank bolted to the masonry wall at the south end of the bridge. The bench mark consists of a point on the stone coping at the south end of the bridge, and is 17.30 feet above gage datum.

Gage readings are furnished by the city engineer of Pueblo. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 230; 1897, Nineteenth Annual Report, Part IV, page 357; 1898, Twentieth Annual Report, Part IV, page 336. The following discharge measurements for 1899 were made under the direction of A. L. Fellows:

Measurements of Arkansas River at Pueblo, Colorado.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Sec.-feet.*	1899.	*Feet.*	*Sec.-feet.*
Apr. 27	0.8	695	Aug. 5	1.46	1,938
May 26	2.2	2,221	Aug. 14	1.20	1,496
June 3	2.55	2,856	Sept. 10	—0.5	180
June 17	3.60	4,565	Sept. 18	—0.10	388
July 1	2.22	2,959	Oct. 6	—0.20	331
July 8	1.61	2,098	Nov. 7	0.05	411
Aug. 1	0.72	1,199			

Daily gage height, in feet, of Arkansas River at Pueblo, Colorado, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.40	0.36	0.59	0.49	0.75	2.50	2.10	c1.00	—0.23	(b)	0.05	—0.10
2	.35	.52	.75	.45	.80	2.50	2.10	.80	— .22	—0.35	.02	— .12
3	.30	.57	.59	.50	.80	2.50	2.40	.90	(b)	— .30	.07	(b)
4	.55	.62	.68	.44	.60	2.20	2.10	1.15	— .20	— .31	.04	— .10
5	.55	.60	.60	.40	.55	1.90	1.90	1.55	— .25	— .26	(b)	— .30
6	.58	.62	.51	.47	.50	1.70	1.80	(b)	— .35	— .20	.00	— .25
7	.43	.60	.62	.47	.55	2.00	2.20	1.10	— .38	— .30	.05	— .30
8	.43	.62	.63	.47	.65	2.10	1.60	.97	— .40	(b)	.00	— .18
9	.45	.60	.59	.34	.65	2.20	1.50	.85	— .32	— .28	— .02	— .20
10	.47	.58	.61	.30	.75	2.30	1.40	.60	(b)	— .32	.01	(b)
11	.39	.75	.47	.29	.85	2.40	1.20	.30	— .50	— .30	— .01	— .15
12	.37	.72	.45	.29	1.30	2.80	1.80	.35	— .48	— .33	(b)	— .28
13	.45	.70	.40	.40	1.70	3.30	2.00	(b)	— .60	— .25	.00	— .05
14	.48	.70	.37	.40	2.00	3.30	1.90	d1.90	— .55	— .20	— .02	.00
15	.49	1.05	.20	.45	2.15	3.60	1.90	.40	— .50	(b)	— .01	— .08
16	.49	1.05	.18	.50	2.25	3.70	1.65	.27	— .38	— .15	— .05	— .25
17	.50	1.19	.69	.50	2.25	3.60	1.50	.25	(b)	— .30	— .12	(b)
18	.50	.95	.40	.50	2.35	3.50	1.80	.10	— .05	— .25	— .15	— .05
19	.50	.85	.40	.45	2.25	3.60	2.00	.07	— .20	— .28	(b)	— .12
20	.50	.73	.22	.40	2.45	3.80	1.50	(b)	— .18	— .25	— .13	(e)
21	.47	.70	.30	.50	2.25	3.70	a1.30	— .05	— .15	— .20	— .15	— .28
22	.50	.70	.25	.20	2.05	3.70	1.10	— .20	— .25	(b)	— .16	(e)
23	.55	.70	.20	.20	1.75	3.30	1.10	— .10	— .30	— .05	— .18	(e)
24	.52	.45	.35	.20	1.65	2.90	1.10	— .15	(b)	— .11	— .10	(b)
25	.45	.67	.35	.40	2.05	2.80	.90	— .30	— .35	— .15	— .08	(b)
26	.40	.65	.45	.45	2.28	2.60	.80	— .35	— .39	— .03	(b)	.05
27	.30	.50	.45	.70	2.50	2.60	1.10	(b)	— .40	— .00	— .20	— .05
28	.37	.59	.31	.78	2.55	2.20	1.00	— .33	— .42	.02	— .22	— .08
29	.37	.....	.36	.90	2.45	2.20	.80	— .35	— .45	(b)	— .20	— .10
30	.37	.....	.33	.80	2.50	2.30	1.10	— .45	— .45	.08	(b)	— .05
31	.35	.....	.40	.....	2.50	.....	.90	— .40	.....	.08	.....	(b)

a New rating table from June 21.
b No record.
c Gage heights after July 31 are from city engineer's records.
d August 19, storm in Pueblo; water rose to 7 feet in night.
e Ice gorge; discard readings.

ARKANSAS RIVER AT NEPESTA, COLORADO.

This station, established September 8, 1897, is located 1,000 feet north of Nepesta, Colorado, at a wagon bridge. The gage consists of a vertical timber securely fastened to the upstream cylinder of bridge, on the left side of the river. The channel above and below the sta-

tion is straight for several hundred feet, while the bed is sandy and shifting, and the results, therefore, are not altogether satisfactory for the purpose of making a rating table. This station is maintained by The Great Plains Water Company. The results of discharge measurements may be found as follows: 1897, Nineteenth Annual Report, Part IV, page 358; 1898, Twentieth Annual Report, Part IV, page 337. The following discharge measurements were made under the direction of A. L. Fellows in 1899:

May 29, gage height, 4.60 feet; discharge, 1,810 second-feet.
June 7, gage height, 4.63 feet; discharge, 1,636 second-feet.
August 3, gage height, 4 feet; discharge, 610 second-feet.
August 25, gage height, 3.10 feet; discharge, 215 second-feet.
October 2, gage height, 3.12 feet; discharge, 213 second-feet.

Daily gage height, in feet, of Arkansas River at Nepesta, Colorado, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	3.50	4.80	5.50	4.10	3.40	3.00	5.20	3.10
2	.....	3.60	4.70	5.30	4.00	3.10	3.00	3.70	3.10
3	.....	3.50	4.80	5.70	4.20	3.10	3.00	3.70	(b)
4	.....	3.50	4.50	5.50	4.90	3.10	3.10	3.50	.....
5	.....	3.40	4.30	5.20	5.80	3.00	3.20	3.20	.....
6	.....	3.30	4.30	5.10	5.50	3.00	3.20	3.30	.....
7	.....	3.40	4.70	5.00	5.10	3.00	3.20	3.50	.....
8	.....	3.50	4.70	5.20	4.20	3.00	3.20	3.50	.....
9	.....	3.50	4.70	4.90	4.20	3.00	3.10	3.50	.....
10	.....	3.70	4.80	4.90	3.90	2.80	3.10	3.40	.....
11	.....	3.70	5.00	4.50	3.60	3.00	2.90	3.50	.....
12	.....	3.90	5.30	4.70	3.40	2.90	3.00	3.60	.....
13	.....	4.50	5.20	4.20	3.20	2.90	3.10	3.50	.....
14	.....	4.60	5.10	5.10	a7.50	2.80	3.30	3.50	.....
15	.....	4.60	5.30	5.80	4.40	3.00	3.10	3.30	.....
16	.....	4.60	5.50	6.00	3.50	3.40	3.00	3.30	.....
17	.....	4.50	5.50	5.90	3.40	3.10	3.10	3.20	.....
18	.....	4.60	5.40	5.50	3.10	3.30	3.20	3.30	.....
19	.....	4.40	5.50	5.40	2.90	3.20	3.10	3.20	.....
20	.....	4.50	5.60	5.20	3.40	3.10	3.10	3.20	.....
21	3.50	4.50	5.80	4.90	3.20	3.10	3.20	3.10	.....
22	3.40	4.50	5.70	4.70	3.30	3.10	3.20	3.10	.....
23	3.00	4.50	5.70	5.00	2.90	3.00	3.30	3.20	.....
24	3.20	4.40	5.50	5.80	3.00	3.00	3.30	3.20	.....
25	3.20	4.50	5.30	4.00	3.10	3.10	3.30	3.30	.....
26	3.30	4.70	5.20	4.00	3.00	3.00	3.40	3.10	.....
27	3.50	4.80	5.10	4.00	3.20	3.00	3.40	3.10	.....
28	3.50	4.80	5.10	5.00	3.20	2.90	3.50	3.00	.....
29	3.40	4.60	5.00	7.00	3.10	2.80	3.40	3.00	.....
30	3.40	4.60	5.10	4.90	3.00	2.90	3.40	3.00	.....
31	.....	4.90	.....	4.90	3.00	.....	3.50	.....	.....

a Flood at Pueblo. b Records discontinued December 2.

ARKANSAS RIVER AT ROCKYFORD, COLORADO.

This station is located 2 miles northeast of Rockyford, Colorado, and was established May 3, 1897. The gage consists of a vertical timber fastened to the abutment of the wagon bridge on the left side of the stream. Both banks are low, but not liable to overflow, excepting at very high water. The bed is sandy and shifting. S. W. Cressy, commissioner of Colorado irrigation district No. 17, is the voluntary observer. On October 16 Rockyford ditch near by was measured at the rating flume, at a gage height of 1.13 feet, and gave a discharge of 41 second-feet. The results of measurements may be

found as follows: 1898, Twentieth Annual Report, Part IV, page 338. The measurements for 1899, made by A. L. Fellows, are as follows:

May 30, gage height, 1.88 feet; discharge, 1,042 second-feet.
October 16, gage height, 0.88 foot; discharge, 136 second-feet.

Daily gage height, in feet, of Arkansas River at Rockyford, Colorado, for 1899.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	1.34	1.10	2.12	2.10	1.82	0.81	0.68	1.70	0.80
2	.....	1.30	1.15	2.10	2.20	1.45	.97	.52	1.90	.80
3	.....	1.32	1.30	2.08	2.35	1.19	.95	.50	1.25	.80
4	.....	1.31	1.05	2.01	3.10	1.45	.74	.65	1.18	.80
5	.....	1.25	.90	1.89	2.28	4.40	.83	.72	1.18	.88
6	.....	1.12	.90	1.62	2.10	2.85	.90	.74	1.00	1.00
7	.....	1.02	.89	1.91	2.00	2.85	.90	.72	1.03	1.00
8	.....	1.02	.90	2.10	2.58	2.20	.88	.79	1.04	.95
9	.....	1.10	.89	2.40	2.05	1.78	.76	.79	1.05	a 1.00
10	.....	1.05	.92	2.05	1.85	1.59	.70	.75	1.08	.....
11	.....	1.00	1.28	1.96	1.78	1.34	.72	.74	1.05	.....
12	.....	.99	1.35	2.15	1.65	1.20	.74	.65	1.09	.....
13	1.35	.95	1.48	2.20	1.48	1.11	.76	.68	1.12	.....
14	1.30	.95	1.63	2.20	3.40	2.25	.78	.80	1.14	.....
15	1.28	.95	1.81	2.50	3.30	2.25	.82	.89	1.16	.....
16	1.25	.....	1.79	2.60	3.20	1.48	.87	.88	1.03	.....
17	1.10	1.20	1.80	2.70	3.85	1.27	1.02	.85	1.00	.....
18	1.05	1.20	1.80	2.75	2.40	1.18	1.01	.86	.85	.....
19	1.00	1.22	1.91	2.65	3.00	1.10	1.12	.92	.75	.....
20	1.00	1.16	1.75	2.80	2.80	1.07	1.25	.94	.....	.....
21	.97	1.10	1.85	2.85	2.40	1.19	1.00	.95	1.20	.....
22	.93	1.16	2.05	2.85	2.15	1.17	1.00	.....	1.00	.....
23	.90	1.17	1.95	2.98	1.95	1.08	.98	.....	.98	.....
24	1.10	1.02	1.90	2.72	1.88	.95	1.00	1.00	1.00	.....
25	1.15	.90	1.80	2.68	2.01	.80	.94	1.00	.95	.....
26	.90	.90	1.95	2.50	1.48	.75	.90	1.01	.92	.....
27	.90	.95	2.02	2.30	1.25	.88	.80	1.02	.91	.....
28	1.27	.97	2.05	2.20	1.12	.88	.82	1.06	.91	.....
29	1.25	.95	2.08	2.05	3.20	.90	.84	1.09	.94	.....
30	1.20	1.10	1.90	1.92	2.45	.90	.72	1.13	.82	.....
31	1.38	.....	1.85	.....	2.92	.80	.....	1.10	.....	.....

a Readings discontinued December 9.

ARKANSAS RIVER AT LA JUNTA, COLORADO.

This station is situated at the head of the Fort Lyons canal, measurements being taken of the water in the rating flume of the canal, of that in its wasteway, and of that passing over the dam at the head of the canal. The station is maintained by The Great Plains Water Company. On May 30, at gage height of 3.90 feet, the discharge of the canal was 772 second-feet, and 22 second-feet was in the wasteway. October 17 the canal was carrying, at a gage height of 1.89 feet, a discharge of 159 second-feet, with 44 second-feet in the wasteway. Continuous records of gage heights were not kept throughout the year. Three measurements of discharge were made by A. L. Fellows of the amount of water passing over the dam, for the purpose of securing a rating table for the form of weir of which the Fort Lyons dam is typical. The first, on May 30, at a gage height of 0.05 foot, gave a discharge of 246 second-feet. The second, on June 13, with a gage height of 0.47 foot, showed a discharge of 857 second-feet, and the last measurement, on June 20, with a gage height of 0.67 foot, gave a discharge of 1,181 second-feet.

PURGATORY RIVER AT TRINIDAD, COLORADO.

This stream is one of the principal tributaries entering the Arkansas River from the south; it rises in northern New Mexico and flows in a general northeasterly direction across the plains, entering the main stream a short distance below Las Animas. The rod is attached to the downstream side of the cylindrical pier of the Las Animas street bridge in the city of Trinidad, and has been maintained for a number of years. Owing, however, to the unsatisfactory condition of the river at this locality, the station was discontinued July 31, 1899. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 232; 1897, Nineteenth Annual Report, Part IV, page 359; 1898, Twentieth Annual Report, Part IV, page 341. Two measurements of discharge were made in 1899 by A. L. Fellows. The first one, on April 28, at a gage height of 3.60 feet, gave a discharge of 52 second-feet; one on July 12, at a gage height of 3.30 feet, showed a discharge of 4 second-feet.

Daily gage height, in feet, of Purgatory River at Trinidad, Colorado, for 1899.

Day.	Apr.	May.	June.	July.	Day.	Apr.	May.	June.	July.	Day.	Apr.	May.	June.	July.
1	3.50	3.95	3.70	3.40	12	3.50	3.80	3.60	3.85	23	3.75	3.75	3.60	4.15
2	3.50	3.85	3.70	3.75	13	3.50	3.80	3.55	4.65	24	3.80	3.60	3.70	3.65
3	3.50	3.75	3.70	3.95	14	3.55	3.80	3.50	4.80	25	3.80	3.60	3.55	3.60
4	3.50	3.70	3.70	3.75	15	3.60	3.85	3.55	4.70	26	3.85	3.60	3.40	3.50
5	3.50	3.80	3.70	3.60	16	3.70	4.00	4.20	4.15	27	3.90	3.60	3.40	3.50
6	3.50	3.70	3.55	3.50	17	3.70	4.00	4.00	3.95	28	3.90	3.60	3.30	4.75
7	3.50	3.70	3.50	3.55	18	3.80	3.90	3.90	4.25	29	3.90	3.60	3.30	4.90
8	3.50	3.65	3.50	3.70	19	3.85	3.85	3.75	4.05	30	3.95	3.60	3.30	4.20
9	3.50	3.80	3.55	3.60	20	3.90	3.90	3.60	3.85	31	.....	3.70	.....	3.85
10	3.50	3.80	3.60	3.50	21	3.95	3.90	3.60	3.70					
11	3.50	3.80	3.50	3.40	22	3.75	3.95	3.55	3.60					

ARKANSAS RIVER AT AMITY CANAL HEAD GATES, COLORADO.

This station is located at the head of Amity canal, 7 miles west of Lamar, Colorado, and is maintained by the Amity Canal Company. The observations here are not as satisfactory as they might be for determining the total flow of the river. The following measurements were made by A. L. Fellows on the canal and wasteway: May 31, the canal, at a gage height of 2.63 feet, was discharging 249 second-feet, while there were 129 second-feet in the wasteway; on June 18 the amount of water in the wasteway, at a gage height of 2.15 feet, was 114 second-feet. No measurements of the main river were made during 1899.

The Arkansas River at the head of the Colorado and Kansas canal, 12 miles west of Lamar, was measured September 8, 1899, and at a gage height of 0.20 feet on the dam was discharging 16 second-feet.

Daily gage height, in feet, of Arkansas River at Amity canal head gates, Colorado, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	Day.	Jan.	Feb.	Mar.	Apr.	May.
1	1.50	1.40	5.60	2.10	0.40	17	1.80	2.00	4.50	1.50	2.10
2	1.50	1.40	5.80	1.90	.30	18	1.80	2.00	2.50	1.50	2.10
3	1.80	1.40	5.60	1.90	.10	19	1.80	2.40	2.50	1.50	2.70
4	1.80	1.40	5.80	1.80	.10	20	2.00	2.40	2.30	1.70	2.20
5	2.00	1.40	5.80	1.80	.10	21	2.20	2.60	2.20	1.60	2.60
6	2.00	1.40	5.00	1.70	1.30	22	2.80	2.80	2.10	1.60	2.00
7	2.00	1.40	4.80	1.90	.60	23	2.60	2.80	2.00	1.20	1.80
8	2.00	1.40	4.80	1.80	.30	24	2.40	2.80	2.00	1.10	3.30
9	2.00	1.40	4.80	1.90	.40	25	2.40	2.60	1.90	1.10	3.10
10	2.00	1.40	4.80	2.00	.20	26	2.40	2.60	2.00	.90	3.30
11	2.00	1.40	4.80	2.20	.20	27	2.40	2.60	1.80	.80	3.10
12	1.80	1.60	4.80	2.20	.20	28	2.70	2.60	2.50	.50	3.90
13	1.80	1.60	4.00	2.20	.20	29	2.60	.....	2.10	.30	4.00
14	1.80	1.80	4.00	2.10	.60	30	2.20	.....	2.40	.30	3.90
15	1.80	1.80	4.60	1.80	1.20	31	1.90	.....	2.00	.....	3.30
16	1.80	2.00	4.60	1.60	1.80						

ARKANSAS RIVER AT GRANADA, COLORADO.

This station was established July 24, 1898, and is located at the head gates of the Buffalo Creek canal, 2 miles northeast of Granada. There is an earth dam across the river at this point, with a footbridge over it, from which measurements were to have been attempted, but, owing to an occasional breaking of the dam during high stages of the river, none have been made since the station was established. The gage is vertical, well painted, and nailed to the head gates of the canal.

Daily gage height, in feet, of Arkansas River at Granada, Colorado, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.40	1.40	2.40	0.30	0.40	0.60	0.60	2.20	0.60	0.80	1.00	0.80
2	.40	1.40	2.40	.30	.60	.40	.60	1.80	.60	.80	1.20	.80
3	.50	1.40	2.40	.30	.80	.40	.80	1.00	.60	.80	3.00	.80
4	.40	1.60	2.40	.30	1.00	.80	.80	.80	.60	.80	2.00	.80
5	.40	1.60	2.40	.30	1.00	.60	3.00	1.40	.60	.80	1.00	1.00
6	.40	1.60	2.00	.30	1.00	.80	2.60	5.40	.60	.80	1.00	1.00
7	.40	1.60	1.60	.30	.80	.80	1.00	3.60	.60	.80	1.00	1.20
8	1.00	1.60	1.60	.30	.60	.80	.80	2.50	70	.80	.80	1.20
9	1.00	1.60	1.40	.30	.60	1.00	.80	1.90	1.00	.80	.80	1.40
10	1.00	1.60	1.40	.30	.60	1.00	2.00	1.60	1.00	.80	.80	1.50
11	1.00	1.60	1.40	.30	.80	1.00	1.60	1.00	1.00	.80	.80	1.50
12	1.00	1.60	1.40	.30	.80	1.20	1.00	.60	.80	.80	.80	1.50
13	1.40	1.60	1.40	.20	.50	.80	2.00	.60	.60	.80	.80	2.00
14	1.40	1.80	1.40	.30	.50	.60	3.50	.60	.60	.80	.80	2.00
15	1.40	1.80	1.40	.80	.50	1.20	4.00	.60	.60	.80	.80	2.00
16	1.40	1.80	1.40	.80	.60	1.40	3.80	2.00	.60	.80	.80	2.50
17	1.40	1.80	1.40	.80	.60	1.00	4.00	1.50	.60	.80	.80	2.50
18	1.00	1.80	1.40	.60	.60	1.00	4.60	1.00	.60	.80	.80	2.50
19	1.00	2.00	.80	.60	.80	2.40	3.60	.80	.60	.80	.80	2.50
20	1.00	2.00	.60	.80	.80	.60	5.00	.80	.60	.80	.86	2.50
21	1.60	2.00	.60	.60	.60	.60	2.80	.80	.80	.80	.80	2.50
22	1.60	2.00	.60	.80	.60	1.20	2.00	.60	.80	.80	.80	2.50
23	1.80	2.00	.60	.60	.60	2.00	1.60	.60	.80	.80	2.20	3.00
24	1.40	2.00	.30	.60	.60	3.00	1.00	.60	.80	.80	1.10	3.00
25	1.40	2.40	.30	.40	.60	2.20	.80	.70	.80	.80	.80	3.00
26	1.40	2.40	.30	.60	.80	2.30	.80	.80	.80	.80	.80	3.00
27	1.40	2.40	.30	.60	.60	2.30	.80	.60	.80	.80	.80	3.00
28	1.60	2.40	.30	.60	.60	1.40	.80	.60	.80	.80	.80	3.00
29	1.60	.....	.50	.60	.80	1.00	3.00	.60	.80	.80	.80	3.00
30	1.80	.....	.50	.60	1.00	.80	1.60	.60	.80	.80	.80	3.00
31	1.40	.....	.40	.....	1.20	.....	2.80	.60	.....	.80	.....	3.60

ARKANSAS RIVER AT HUTCHINSON, KANSAS.

The Arkansas River, after crossing the Kansas and Colorado State line, is not systematically measured until Hutchinson, in about the center of the State, is reached. The station here was established May 13, 1895, and is located at the wagon bridge at the south end of Main street. The gage consists of an oak timber spiked to a pile a few feet above the bridge. Bench mark No. 1 is the upper crosspiece of the pier guard, with an elevation of 8.35 feet above zero of the gage. Bench mark No. 2 is the top of the iron doorsill of the first brick building next to the river, and its elevation is 8.12 feet above gage datum. The channel is straight for some distance above and below the bridge; the bed is sandy and very shifting. Results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 233; 1897, Nineteenth Annual Report, Part IV, page 361; 1898, Twentieth Annual Report, Part IV, page 343. Discharge measurements for 1899 were made by W. G. Russell, as follows:

May 2, gage height, 1.45 feet; discharge, 63 second-feet.
June 13, gage height, 3.95 feet; discharge, 2,790 second-feet.
June 14, gage height, 3.85 feet; discharge, 2,772 second-feet.
October 17, gage height, 1.20 feet; discharge, 30 second-feet.

Daily gage height, in feet, of Arkansas River at Hutchinson, Kansas, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.80	2.00	2.15	2.20	1.50	1.40	2.10	2.95	1.60	1.30	1.70	1.70
2	1.90	------	2.50	2.20	1.55	1.35	2.10	2.80	1.50	1.20	1.70	1.70
3	1.95	------	2.95	2.20	1.60	1.50	2.20	2.75	1.50	1.20	1.65	1.70
4	2.00	2.00	2.85	2.15	1.65	2.30	2.20	2.65	1.50	1.20	1.55	1.70
5	2.00	(a)	2.90	2.15	1.60	2.15	2.15	2.60	1.50	1.20	1.50	1.70
6	2.00	(a)	3.15	2.20	1.60	2.00	2.10	2.55	1.50	1.20	1.50	1.70
7	1.90	(a)	3.20	2.20	1.50	2.00	2.20	2.55	1.50	1.20	1.50	1.70
8	1.90	(a)	3.25	2.20	1.50	2.65	2.20	2.60	1.50	1.20	1.50	1.70
9	2.00	(a)	3.00	2.20	1.50	3.10	2.05	2.55	1.50	1.20	1.50	1.70
10	2.00	(a)	2.90	2.15	1.60	3.30	2.00	2.80	1.55	1.20	1.50	1.70
11	1.70	(a)	3.05	2.05	1.55	3.35	2.00	4.15	1.50	1.20	1.50	1.70
12	1.70	(a)	2.85	2.00	1.50	4.35	1.95	3.80	1.50	1.20	1.50	1.80
13	1.70	(a)	2.80	2.00	1.45	3.90	1.90	3.65	1.40	1.20	1.50	1.90
14	1.70	(a)	2.90	1.90	1.40	3.80	1.90	3.60	1.40	1.20	1.50	1.90
15	1.70	(a)	2.90	1.85	1.40	3.65	1.90	3.35	1.40	1.20	1.50	1.90
16	1.80	(a)	2.65	1.80	1.40	3.30	1.85	3.05	1.45	1.20	1.50	2.00
17	1.80	2.30	2.60	1.80	1.40	2.90	1.80	2.75	1.50	1.20	1.50	2.00
18	2.10	2.30	2.60	1.80	1.40	2.65	1.80	2.55	1.50	1.20	1.50	2.00
19	2.10	2.15	2.50	1.70	1.40	2.45	1.80	2.50	1.40	1.20	1.50	2.00
20	2.10	2.05	2.50	1.70	1.40	2.40	1.80	2.35	1.40	1.20	1.50	2.00
21	2.00	2.10	2.50	1.70	1.40	2.25	1.95	2.20	1.40	1.20	1.50	2.00
22	2.00	2.25	2.50	1.65	1.50	2.20	3.95	2.20	1.40	1.20	1.60	2.00
23	2.00	2.30	2.45	1.60	1.50	2.30	4.55	2.15	1.40	1.20	1.70	2.00
24	2.10	2.30	2.40	1.60	1.55	2.30	4.35	2.00	1.30	1.20	1.70	2.00
25	2.00	2.30	2.35	1.60	1.50	2.35	4.45	1.90	1.30	1.50	1.70	2.00
26	2.00	2.30	2.30	1.60	1.40	2.40	4.05	1.90	1.30	1.75	1.70	1.90
27	2.10	2.25	2.45	1.60	1.40	2.40	3.70	1.80	1.30	1.80	1.70	1.80
28	2.10	2.15	2.35	1.55	1.40	2.40	3.35	1.75	1.30	1.80	1.70	1.80
29	------	------	2.20	1.50	1.40	2.30	3.25	1.70	1.30	1.80	1.70	1.80
30	2.00	------	2.20	1.50	1.40	2.15	3.20	1.65	1.30	1.80	1.70	1.80
31	------	------	2.25	------	1.30	------	3.20	1.60	------	1.80	------	1.80

a Frozen.

VERDIGRIS RIVER AT LIBERTY, KANSAS.

This river rises in the southeastern corner of Chase County, Kansas, and has a general southerly direction, passing out of the State near Coffeyville into Indian Territory. It enters Arkansas River 1 mile above the mouth of Grand, or Neosho, River near Fort Gibson.

It is essentially a surface run-off stream; its water is muddy, the fall flood large, the summer flow small, and the fluctuations in height rapid. There are a number of fine water powers located on the main stream and its various tributaries, and many of them were utilized several years ago. In the years 1880 to 1890 it is said that there were eleven dams on the Verdigris River, but at the present time not more than three or four are utilized. The drainage area is mapped on the Independence, Fredonia, Emporia, Eureka, Sedan, Eldorado, Cottonwood Falls, Parkerville, Newton, and Abilene atlas sheets. The station was established in August, 1895, and is located at a wagon bridge about 250 feet below McTaggart's mill dam, about 3 miles southwest of the town of Liberty, Kansas. The gage is a vertical timber fastened to the floor of the mill. Bench mark No. 1 is the heads of three large nails in the flume, and is at an elevation of 12.46 feet above the zero of the gage. Bench mark No. 2 is the head of a spike in the root of a cottonwood tree 40 feet south of the gage, and is at an elevation of 10.98 feet above gage datum. The bed is rocky, composed of gravel and subject to very little change. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 235; 1897, Nineteenth Annual Report, Part IV, page 369; 1898, Twentieth Annual Report, Part IV, page 344. The following discharge measurements were made by E. C. Murphy and W. G. Russell during 1899:

May 19, gage height, 8.03 feet; discharge, 311 second-feet.
June 10, gage height, 21.30 feet; discharge, 16,906 second-feet.
July 6, gage height, 21.50 feet; discharge, 16,505 second-feet.
October 11, gage height, 1.70 feet; discharge, 17 second-feet.

Daily gage height, in feet, of Verdigris River at Liberty, Kansas, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.80	2.80	4.10	4.10	3.65	6.75	2.80	4.50	2.00	1.70	1.90	1.90
2	3.70	2.70	3.80	4.10	3.75	5.15	2.80	4.20	2.00	1.70	1.90	1.90
3	3.20	2.70	3.60	3.80	4.05	3.70	2.75	3.60	2.00	1.70	1.90	1.90
4	3.00	2.70	3.50	3.60	7.35	5.55	12.40	3.15	2.00	1.70	1.90	1.90
5	3.30	2.70	3.50	3.40	6.75	6.35	15.40	3.05	2.00	1.70	1.90	1.90
6	3.30	2.70	3.40	3.60	4.70	8.60	15.95	2.80	2.00	1.70	1.90	1.90
7	3.20	2.70	3.30	3.80	4.85	9.35	8.55	2.75	2.00	1.70	1.80	1.90
8	3.20	2.60	3.20	4.10	5.05	5.80	26.90	2.60	2.00	1.70	1.80	1.90
9	3.20	2.60	3.10	4.00	4.65	10.35	30.45	2.60	2.00	1.70	1.80	1.90
10	3.10	2.60	3.20	3.80	4.45	21.45	19.75	2.50	2.00	1.70	1.80	1.90
11	3.10	2.60	3.20	3.70	4.15	24.05	8.75	2.50	2.00	1.70	1.80	1.90
12	3.10	2.60	7.10	3.60	4.00	24.75	4.90	2.50	2.00	1.70	1.80	2.00
13	3.30	2.50	6.30	3.50	3.85	19.10	4.55	2.40	2.00	1.70	1.80	2.00
14	3.20	2.50	6.00	4.30	3.65	9.15	4.25	2.75	2.00	1.70	1.80	2.00
15	3.10	2.50	5.60	3.70	3.45	5.75	4.20	5.55	2.00	1.70	1.80	2.00
16	3.20	2.50	5.90	3.30	3.20	7.50	4.25	3.40	2.00	1.70	1.80	2.00
17	3.10	2.40	5.00	3.30	3.20	5.65	6.40	2.90	2.00	1.70	1.80	2.00
18	3.20	2.40	4.80	3.70	3.00	4.80	7.65	2.65	2.00	1.70	1.80	2.00
19	3.10	2.40	4.90	3.85	3.00	4.40	7.05	2.45	1.90	1.70	1.80	2.00
20	3.00	2.40	5.80	7.15	6.60	4.05	7.20	2.40	1.90	1.60	1.90	1.90
21	3.00	3.10	4.80	6.45	10.20	3.85	7.65	2.30	1.90	1.60	1.90	1.90
22	3.00	3.20	4.60	8.45	5.10	3.60	7.70	2.30	1.90	1.60	1.90	1.90
23	2.90	3.10	4.10	11.20	6.70	3.40	6.40	2.30	1.90	1.60	1.90	2.00
24	2.90	3.00	3.90	6.50	14.65	3.25	4.75	2.20	1.90	1.60	1.90	2.00
25	2.90	3.10	3.80	5.30	9.65	3.20	4.10	2.20	1.90	1.60	1.90	2.00
26	3.00	6.60	3.70	4.70	4.80	3.35	3.85	2.20	1.80	1.90	1.90	2.00
27	3.00	6.00	3.50	4.45	4.40	3.20	3.65	2.10	1.80	2.00	1.90	2.00
28	3.00	4.50	3.50	4.25	4.00	3.05	3.45	2.10	1.80	2.00	1.90	2.10
29	3.00	.....	3.40	4.35	4.00	3.00	3.15	2.00	1.70	2.00	1.90	2.10
30	3.00	.....	3.70	3.80	3.70	2.85	3.10	2.00	1.70	2.00	1.90	2.10
31	2.90	.....	4.10	.....	3.45	.....	3.85	2.00	.....	2.00	.....	2.10

NEOSHO RIVER AT IOLA, KANSAS.

This river drains a long, narrow strip in southeastern Kansas, extending into Indian Territory. The upper part of the basin has a general east-west direction, draining the area immediately south of Kansas River and north of the headwaters of Verdigris River. The general direction of the river bends gradually southward between Emporia and Iola, and that direction is maintained for the rest of its course. Neosho River in Indian Territory is known as Grand River. During the last season two gaging stations were maintained in the basin—one at Iola, the other at Fort Gibson, near the mouth. The former station was established in July, 1895, and is located at the highway bridge 1 mile west of the city of Iola, Kansas. The gage is fastened to the head gates of the flume about 90 feet above the bridge. The bench mark is the heads of three large nails driven into the crosspiece of the flume, and is 13.30 feet above the datum of the gage. Results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 238; 1897, Nineteenth Annual Report, Part IV, page 362; 1898, Twentieth Annual Report, Part IV, page 346. The following discharge measurements were made by E. C. Murphy and W. G. Russell during 1899:

May 18, gage height, 2.70 feet; discharge, 242 second-feet.
June 9, gage height, 18 feet; discharge, 27,959 second-feet.
July 5, gage height, 8.20 feet; discharge, 6,313 second-feet.
July 8, gage height, 16.70 feet; discharge, 25,849 second-feet.
October 11, gage height, 2.30 feet; discharge, 316 second-feet.

Daily gage height, in feet, of Neosho River at Iola, Kansas, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.00	2.70	3.60	3.85	3.10	4.50	2.80	2.80	2.70	2.30	2.00	2.00
2	2.90	2.60	3.55	3.70	3.10	5.20	2.80	2.70	2.70	2.30	2.00	2.00
3	2.90	2.60	3.60	3.70	3.00	4.45	3.00	2.70	2.60	2.30	2.00	2.00
4	2.80	2.60	3.60	4.20	3.10	4.80	12.50	2.70	2.60	2.30	2.00	2.00
5	2.80	2.60	3.65	4.40	3.10	6.30	8.90	2.60	2.60	2.30	2.00	2.00
6	2.80	2.60	3.70	4.00	3.00	7.95	5.80	2.50	2.50	2.30	2.00	2.00
7	2.80	2.60	3.70	3.85	3.10	6.60	14.00	2.60	2.50	2.30	2.00	2.00
8	2.70	2.60	3.60	3.60	3.10	5.55	16.50	3.05	2.45	2.30	2.00	2.00
9	2.70	2.60	3.50	3.60	3.10	17.03	9.80	2.90	2.40	2.25	2.00	2.00
10	2.80	2.50	3.50	3.50	3.15	15.70	6.60	2.80	2.40	2.20	2.00	2.00
11	2.80	2.50	4.90	3.50	3.30	11.40	4.50	2.70	2.40	2.20	2.00	2.00
12	2.80	2.50	11.05	3.40	3.50	11.50	3.75	2.60	2.40	2.20	2.00	2.10
13	2.90	2.50	6.05	3.40	3.40	9.20	3.25	2.50	2.40	2.20	2.00	2.10
14	2.90	2.60	5.45	3.40	3.40	5.60	3.00	2.50	2.40	2.20	2.00	2.10
15	2.90	2.70	5.00	3.40	3.25	4.75	3.65	2.50	2.40	2.20	2.00	2.10
16	2.90	2.80	4.50	3.30	3.00	4.40	4.65	2.55	2.40	2.20	2.00	2.10
17	2.90	2.90	4.85	3.20	2.90	4.20	4.80	3.30	2.40	2.10	2.00	2.20
18	2.90	2.95	7.55	3.20	2.85	4.10	4.10	3.00	2.40	2.10	2.00	2.20
19	2.80	3.10	5.85	3.10	2.85	4.05	3.60	2.80	2.40	2.10	2.00	2.20
20	2.80	3.15	5.40	4.50	2.90	3.85	3.95	2.80	2.40	2.10	2.00	2.20
21	2.80	3.20	5.15	4.05	2.90	3.70	5.35	2.60	2.40	2.10	2.00	2.20
22	2.80	3.30	4.65	3.80	2.90	3.60	6.40	2.60	2.40	2.10	2.00	2.20
23	2.80	3.40	4.10	3.75	4.65	3.50	3.50	2.60	2.40	2.10	2.00	2.10
24	2.80	3.60	3.85	3.60	6.60	3.25	3.35	2.50	2.40	2.10	2.00	2.10
25	2.80	3.95	3.65	3.50	4.90	3.15	3.05	2.50	2.40	2.00	2.00	2.10
26	2.80	5.95	3.55	3.40	6.95	3.10	3.00	2.60	2.40	2.00	2.00	2.10
27	2.80	4.70	3.70	3.30	6.55	3.05	2.85	2.60	2.40	2.00	2.00	2.10
28	2.70	3.90	3.90	3.20	4.45	3.00	2.80	2.60	2.40	2.00	2.00	2.10
29	2.70	.....	4.20	3.10	3.85	2.90	2.70	2.85	2.40	2.00	2.00	2.10
30	2.70	.....	4.20	3.10	3.70	2.80	2.70	2.85	2.40	2.00	2.00	2.10
31	2.70	.....	3.95	.....	3.25	.....	2.70	2.75	.....	2.00	.....	2.10

GRAND RIVER AT FORT GIBSON, INDIAN TERRITORY.

In its lower course through Indian Territory Neosho River is known as Grand River. The station was established by W. G. Russell, May 16, 1899, at the railroad bridge one-half mile north of the station at Fort Gibson and 3 miles above the mouth of the river. The rod is spiked to the ties of the bridge. The initial point for soundings is the left end of the bridge. The channel is straight for some distance both above and below the station. The right bank is liable to overflow, while the left is not, being high and rocky. The bed of the stream is sandy and shifting at the right side and toward the center. W. Blackwell, railroad pump man, is the observer. Two measurements of discharge were made here by W. G. Russell during 1899. The first one was on May 16, at a gage height of 15.00 feet, and showed a discharge of 19,823 second-feet; the second measurement was on October 12, with a gage height of 9.20 feet, and gave a discharge of 1,070 second-feet.

Daily gage height, in feet, of Grand River at Fort Gibson, Indian Territory, for 1899.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	13.80	12.80	15.20	10.90	10.00	10.00	11.90
2	.....	13.80	13.00	15.00	10.90	10.00	10.00	11.80
3	.....	13.80	13.00	14.80	10.40	10.00	10.00	11.60
4	.....	14.70	13.20	14.90	10.20	10.00	10.00	11.40
5	.....	13.60	13.70	14.40	10.20	10.00	10.00	11.10
6	.....	13.00	14.00	14.20	10.10	10.00	10.00	11.00
7	.....	12.90	14.60	14.00	10.00	10.00	10.00	10.80
8	.....	16.20	14.70	13.90	10.00	9.90	10.00	10.50
9	.....	16.00	14.80	13.70	10.00	9.90	10.00	10.40
10	.....	16.30	14.90	13.30	10.00	9.80	10.00	10.40
11	.....	15.20	15.00	13.20	10.00	9.70	10.00	10.20
12	.....	17.20	15.40	13.00	10.00	9.20	10.00	10.00
13	.....	19.00	15.90	13.00	10.00	9.20	10.00	10.00
14	.....	19.80	16.00	12.90	10.00	9.10	10.00	10.00
15	.....	19.60	16.80	12.90	10.00	9.10	10.00	10.00
16	15.00	17.60	17.00	12.80	10.00	9.10	10.00	10.00
17	15.00	16.60	17.60	12.70	9.90	9.00	10.00	10.00
18	13.60	15.60	17.90	12.60	9.80	9.00	10.00	10.00
19	13.50	14.50	17.90	12.60	9.70	9.00	10.20	10.00
20	13.40	14.00	17.60	12.40	9.70	9.00	10.40	10.00
21	13.30	14.00	17.40	12.20	9.70	9.00	10.60	10.00
22	14.30	14.00	17.40	12.10	9.60	9.10	11.00	10.00
23	14.70	13.80	17.00	12.00	9.60	9.10	11.20	10.00
24	15.60	13.80	17.00	12.00	9.70	9.10	11.50	10.00
25	15.10	13.10	16.80	11.90	9.80	9.20	11.80	10.10
26	14.80	13.00	16.60	11.80	9.80	9.20	12.00	10.20
27	14.80	13.00	16.00	11.80	9.80	9.50	12.00	10.30
28	14.80	13.00	16.00	11.60	9.90	9.50	12.00	10.40
29	14.80	13.00	15.80	11.40	9.90	9.60	12.00	10.40
30	13.80	13.00	15.60	11.20	9.90	9.70	11.90	10.50
31	13.80	.....	15.40	11.00	.....	9.80	.....	10.60

NORTH FORK OF CANADIAN RIVER AT OKLAHOMA, OKLAHOMA.

This stream rises in the extreme northeast corner of the panhandle of Texas. Its general course across Oklahoma and Indian Territory is southeasterly, emptying into the main Canadian River 45 miles above its mouth. The basin is a long, narrow area located between Cimarron River on the north and the main Canadian River on the

south. Two gaging stations are maintained on the river, one at Oklahoma, Oklahoma, and the other at Eufaula, Indian Territory. The former station was established by W. G. Russell May 19, 1899, and is located at the highway bridge, east of the Atchison, Topeka and Santa Fe Railroad bridge, one-half mile south of the town. The right bank is high, but the left is low and liable to overflow. H. E. Smith, a farmer living near by, is the observer. Two measurements of discharge were made by W. G. Russell during 1899, as follows: The first, on May 19, at a gage height of 5.50 feet, gave a discharge of 395 second-feet; the second, on October 15, at a gage height of 2.80 feet, showed a discharge of 22 second-feet.

Daily gage height, in feet, of North Fork of Canadian River at Oklahoma, Oklahoma, for 1899.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	6.10	5.10	9.30	3.30	3.10	3.40	5.50
2	.....	5.90	5.00	8.60	3.20	3.10	3.30	5.50
3	.....	5.70	4.90	8.00	3.30	3.00	3.10	5.40
4	.....	5.60	4.80	7.60	3.20	3.00	3.10	5.30
5	.....	6.20	4.70	7.10	3.20	2.90	3.30	5.20
6	.....	6.50	4.60	6.90	3.20	2.90	3.50	5.10
7	.....	6.20	4.50	6.20	3.20	2.90	3.60	5.00
8	.....	6.90	4.50	5.90	3.20	2.90	3.60	4.10
9	.....	6.20	4.30	5.60	3.10	2.90	3.70	5.20
10	.....	5.90	4.30	5.40	3.30	2.90	3.70	5.10
11	.....	6.50	4.50	5.30	3.20	2.90	3.70	4.90
12	.....	8.00	5.00	5.20	3.10	2.80	3.80	4.80
13	.....	9.30	5.20	5.00	3.10	2.80	3.90	4.70
14	.....	7.80	5.10	4.90	3.00	2.80	4.00	4.60
15	.....	8.00	4.60	4.80	3.00	2.80	4.20	4.50
16	.....	11.10	4.50	4.70	3.00	2.80	4.60	4.40
17	.....	11.00	4.40	4.60	3.00	2.80	5.00	4.40
18	.....	9.40	6.00	4.40	3.10	2.80	5.20	4.40
19	5.50	8.80	4.50	4.30	3.00	2.70	6.00	4.30
20	5.40	8.00	4.30	4.30	3.00	2.70	12.10	4.30
21	5.30	7.80	4.30	4.20	3.00	2.70	13.60	4.60
22	5.20	7.20	5.00	4.10	3.00	2.70	13.50	4.60
23	5.20	7.00	4.80	4.00	3.00	2.60	12.60	4.50
24	5.10	6.80	6.00	3.11	3.60	2.60	7.90	4.40
25	5.00	6.50	6.30	3.10	3.60	2.90	6.00	4.30
26	5.70	6.10	7.50	3.90	3.50	3.00	5.90	4.30
27	6.40	5.90	7.60	3.80	3.40	3.50	5.80	4.20
28	6.40	5.70	8.50	3.70	3.30	4.00	5.70	4.20
29	6.20	5.50	9.60	3.60	3.30	3.00	5.60	4.10
30	5.80	5.30	10.20	3.50	3.30	4.00	5.60	4.10
31	6.20	.....	10.30	3.40	.....	3.70	.....	4.20

NORTH FORK OF CANADIAN RIVER AT EUFAULA, INDIAN TERRITORY.

This station was established by W. G. Russell May 17, 1899, and is located at the railroad bridge of the Missouri, Kansas and Texas Railroad, 5 miles above the mouth of the river and 2 miles north of the town of Eufaula. The channel is straight for some distance both above and below the station. The right bank is high, but the left bank is low and liable to overflow. The bed of the stream is sandy and shifting. H. Erwin, railroad pump man, is the observer. Two measurements of discharge were made during 1899 by W. G. Russell: The first, on May 17, with a gage height of 24.00 feet, gave a discharge of 19,072 second-feet; the second, on October 13, with a gage height of 9.50 feet, gave a discharge of 154 second-feet.

Daily gage height, in feet, of North Fork of Canadian River at Eufaula, Indian Territory, for 1899.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	12.00	11.60	12.00	10.50	10.00	10.00	11.50
2	.....	12.00	11.60	11.60	10.50	9.80	9.80	11.50
3	.....	11.60	11.50	11.60	10.50	9.80	9.70	11.50
4	.....	11.60	11.00	11.50	10.50	9.60	9.50	11.50
5	.....	11.60	11.00	12.00	10.30	9.50	9.50	11.50
6	.....	10.00	10.60	12.00	10.40	9.50	9.50	11.50
7	.....	10.50	10.50	12.00	10.40	9.50	9.50	11.50
8	.....	11.50	10.60	12.00	10.30	9.50	9.40	11.50
9	.....	11.60	10.60	11.60	10.00	9.50	9.40	11.50
10	.....	12.00	10.60	11.60	10.00	9.50	9.40	11.50
11	.....	14.00	11.00	11.50	10.00	9.50	9.30	11.50
12	.....	14.00	11.60	11.50	10.00	9.50	9.40	11.50
13	.....	13.00	12.00	11.50	10.00	9.50	9.40	11.40
14	.....	11.00	12.50	11.50	10.00	9.50	9.40	11.40
15	.....	12.00	12.50	11.50	10.00	9.50	9.30	10.40
16	.....	13.00	11.50	11.40	10.00	9.40	9.20	10.40
17	24.00	14.00	11.00	11.00	10.00	9.40	9.20	10.30
18	23.60	15.00	10.60	11.00	10.00	9.50	9.20	10.50
19	23.00	17.00	11.00	11.00	10.00	9.50	9.20	11.00
20	22.50	20.00	12.60	11.00	10.00	9.40	9.20	11.00
21	21.30	20.00	13.00	11.00	10.00	9.40	9.50	11.00
22	20.50	19.00	13.00	11.00	10.00	9.30	9.60	11.40
23	19.90	16.00	14.00	10.80	10.00	9.20	10.50	11.50
24	20.50	13.00	16.00	10.80	10.00	9.20	10.70	11.50
25	19.60	12.50	18.00	10.80	10.00	9.30	12.00	11.50
26	18.60	12.00	11.50	10.80	10.00	9.30	12.50	11.50
27	18.00	11.50	11.00	10.80	10.00	9.60	12.50	11.30
28	17.60	11.50	11.00	10.70	10.00	10.20	12.50	11.00
29	15.00	11.00	12.00	10.70	10.00	10.00	12.30	10.00
30	12.50	11.50	12.00	10.60	10.00	10.00	12.30	10.00
31	12.00	.....	12.00	10.60	.....	10.00	.....	9.60

WASHITA RIVER AT PAULS VALLEY, INDIAN TERRITORY.

This river rises in the eastern edge of the Texas Panhandle, immediately south of Canadian River. Its general direction is southeasterly through Oklahoma Territory, and then into Indian Territory, emptying into Red River about 11 miles above the crossing of the Missouri, Kansas and Texas Railroad. The gaging station was established by W. G. Russell on May 20, 1899, and is located at the highway bridge, 2 miles east of the town of Pauls Valley, Indian Territory. The channel is straight for some distance above and below the station; the right bank is low and liable to overflow, but the left bank is high. The bed of the stream is sandy and shifting. Two measurements of discharge were made at this point by W. G. Russell in 1899: The first, on May 20, with a gage height of 8.50 feet, gave a discharge of 684 second-feet; the second, made on October 15, at a gage height of 4.60 feet, gave a discharge of 96 second-feet.

Daily gage height, in feet, of Washita River at Pauls Valley, Indian Territory, for 1899.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	7.60	7.30	12.80	5.40	5.10	6.00	8.50
2	.....	6.80	7.20	9.90	5.40	5.00	5.80	8.00
3	.....	6.50	7.00	8 90	5.30	4.90	5.50	7.80
4	.....	6.50	7.00	8 20	5.10	4.80	5.40	7.60
5	.....	6.20	7.00	7.80	5.00	4.80	5.30	7.50
6	.....	6.40	6.90	7.70	5.00	4.70	5.20	7.40
7	.....	7.30	6.80	7.70	5.00	4.70	5.10	7.00
8	.....	8.80	8.30	7.60	4.90	4.70	5.00	6.80
9	.....	7.70	9.50	7.20	5.90	4.70	4.90	7.00
10	.....	7.50	8.50	7.00	4.90	4.70	4.80	7.40
11	.....	9.40	7.70	7.80	4.90	4.70	4.80	7.40
12	.....	8.80	7.00	6.80	4.90	4.70	4.80	7.50
13	.....	9.00	6.90	6.70	4.90	4.60	4.80	7.50
14	.....	9.50	9.00	6.60	4.90	4.50	4.80	7.50
15	.....	10.70	9.10	6.50	4.90	4.60	4.70	8.60
16	.....	11.50	8.50	6.30	4.90	4.60	4.70	8.00
17	.....	12.70	8.00	6.10	5.00	4.60	4.80	7.40
18	.....	16.20	7.50	6.00	5.20	4.60	7.00	7.50
19	.....	15.70	8.90	6.00	5.70	4.50	14.55	7.20
20	8.50	13.70	8.00	5.90	5.50	4.50	20.70	7.00
21	7.90	12.20	7.50	5.80	5.40	4.50	20.70	6.80
22	7.80	11.40	8.90	5.70	5.20	4.50	19.80	6.50
23	7.40	10.50	9.00	5.70	5.20	4.50	19.05	6.60
24	7.40	9.10	9.50	5.80	5.00	4.50	15.75	6.50
25	7.20	8.20	9.30	5.70	6.00	4.70	14.25	6.40
26	7.00	8.00	9.40	5.70	5.70	5.00	15.60	6.30
27	6.90	7.80	8.30	5.50	5.50	6.00	16.50	6.60
28	6.80	7.30	7.80	5.50	5.30	7.50	13.90	6.50
29	6 80	7.50	9.80	5.50	5.30	6.50	11.30	6.50
30	7.00	7.80	12.70	5.40	5.20	6.40	9.00	6.40
31	7.70	.....	14.00	5.40	.....	6.30	.....	6.00

TRINITY RIVER AT DALLAS, TEXAS.

This river rises in Montague and Cooke counties, in northern Texas, the headwater streams draining the area within a few miles of Red River on the north. The general course of Trinity River is southeasterly, and it empties into the Gulf of Mexico at Galveston. The entire basin is located in Texas. The station, established October 1, 1898, is located at Turtle Creek pump house, 3 miles north of the court-house in Dallas. The height of the water is indicated by a pointer which slides up and down in the well of the pump house. This well is connected with the river by a pipe. Measurements of discharge are made by wading. The channel is practically straight above and below the point of measurement. The right bank is high, the left bank low and liable to overflow. The bed of the stream is of gravel and shifting. There was no discharge of the river from June 22 to October 30. Three discharge measurements were made during 1899 by Thomas U. Taylor, as follows: The first one, on June 20, at a gage height of 57 feet, gave a discharge of 269 second-feet; June 22, a gage height of 53.30 feet gave a discharge of 0 second-feet; the third measurement was on December 29, at a gage height of 56.60 feet, and gave a discharge of 336 second-feet.

Daily gage height, in feet, of Trinity River at Dallas, Texas, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	55.50	55.25	55.50	54.20	57.45	55.50	64.60	56.20	52.65	50.35	60.25	59.75
2	55.40	54.90	55.85	54.20	56.85	55.40	63.25	55.75	52.25	50.35	60.45	56.70
3	55.40	54.55	55.80	54.20	56.60	55.30	58.60	55.45	51.80	50.00	60.55	56.45
4	55.40	54.40	55.45	54.20	56.30	55.20	59.05	55.20	51.40	50.25	58.80	56.25
5	55.30	54.60	55.45	54.30	55.85	55.20	63.20	55.20	51.05	49.95	57.30	56.05
6	55.25	54.95	55.00	54.80	55.70	55.15	73.35	54.95	50.25	50.20	56.05	56.00
7	55.15	54.85	54.40	54.65	57.10	55.00	69.60	54.80	51.15	50.20	55.70	56.00
8	55.30	54.65	54.65	54.50	57.50	55.00	59.45	54.80	51.05	50.25	55.55	56.00
9	55.65	54.65	54.45	54.50	58.75	54.95	57.25	54.75	50.80	50.25	55.40	56.05
10	55.55	54.80	53.95	54.50	61.10	55.60	56.75	54.65	49.80	50.30	55.30	56.20
11	55.75	54.40	53.90	54.70	59.00	56.45	56.55	54.55	51.05	50.35	55.15	56.35
12	55.65	54.25	53.90	54.95	59.75	61.70	56.30	54.75	51.20	50.30	54.95	57.75
13	56.30	54.45	54.10	55.00	58.05	62.55	56.20	54.60	51.15	49.75	54.95	59.80
14	59.10	54.55	54.55	54.65	57.55	58.75	56.45	54.50	51.00	50.25	54.95	61.20
15	58.15	54.95	54.35	54.95	57.70	57.95	56.05	54.40	51.15	50.30	54.95	61.80
16	57.50	54.45	54.10	55.80	57.70	57.65	55.70	54.35	50.95	50.30	55.00	60.60
17	56.85	54.80	54.00	56.70	57.75	59.65	55.40	54.35	51.35	50.05	54.60	58.85
18	56.45	54.55	54.65	57.10	58.00	61.10	55.30	54.40	51.40	50.00	54.25	57.55
19	56.05	54.90	54.40	56.60	57.80	58.25	55.45	54.20	50.35	50.00	54.05	56.85
20	55.70	54.45	54.00	56.30	56.95	57.20	55.80	53.75	50.65	50.00	58.20	56.50
21	55.55	54.30	53.95	55.90	56.80	58.20	55.30	53.40	51.30	49.90	67.30	56.50
22	55.45	54.75	54.25	55.65	56.80	58.40	58.25	53.05	51.30	49.80	71.05	57.30
23	55.50	54.40	54.10	55.50	56.80	58.55	57.50	52.75	51.40	49.80	65.45	57.70
24	55.55	54.05	54.05	55.55	57.00	58.60	57.30	52.40	51.10	49.80	62.75	58.40
25	55.40	54.50	54.15	55.60	57.95	57.90	56.65	52.00	50.38	49.80	64.20	57.35
26	55.15	54.40	54.20	57.30	58.00	56.95	56.20	51.55	49.80	49.80	68.10	57.15
27	55.00	54.20	54.25	58.30	58.00	56.40	55.80	51.85	50.25	49.80	71.90	57.25
28	55.20	54.05	54.45	58.55	57.60	56.00	57.10	52.00	50.15	49.95	74.55	56.80
29	55.30	.....	54.30	58.55	56.85	55.90	56.45	52.15	50.00	50.15	76.00	56.55
30	55.25	.....	54.25	58.00	55.85	59.20	55.85	52.35	50.10	53.10	74.45	56.40
31	55.30	.....	54.20	.....	55.65	.....	56.10	52.50	.....	50.30	.....	.....

BRAZOS RIVER AT WACO, TEXAS.

This river has its source in the Staked Plains region of western Texas, and has a general southeasterly course, emptying into the Gulf of Mexico south of the mouth of Trinity River. Its drainage basin is entirely within the State of Texas. The gaging station, established by T. U. Taylor September 14, 1898, is located at the Austin street bridge, northwest of Waco. The gage is inclined, the channel straight, and the banks high. The bed of the stream is of shifting sand. Measurements of discharge have been made under the suspension bridge above the railroad bridge. Under the former, at low water, is a sand bar, which does not, however, affect the reliability of the measurements, as there are then two distinct channels. Three measurements of discharge were made in 1899 by Thomas U. Taylor: The first, on June 19, at a gage height of 18.50 feet, showed a discharge of 58,700 second-feet; the measurement of June 26, at a gage height of 6.90 feet, gave a discharge of 4,430 second-feet; while the third measurement, on December 30, at a gage height of 4.90 feet, showed a discharge of 2,085 second-feet.

Daily gage height, in feet, of Brazos River at Waco, Texas, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.70	2.30	2.20	1.80	2.10	6.00	a15.00	5.30	2.45	1.10	7.10	5.30
2	2.65	2.35	2.25	1.90	2.05	5.45	17.00	5.00	2.40	1.10	6.65	4.90
3	2.60	2.40	2.20	1.90	2.00	4.75	12.45	4.90	2.30	1.10	6.10	4.45
4	2.50	2.40	2.20	1.90	2.40	4.25	11.25	4.70	2.40	2.00	5.65	4.20
5	2.50	2.40	2.15	1.90	2.70	4.00	14.85	4.20	2.30	2.00	5.30	4.05
6	2.50	2.35	2.10	2.20	2.70	3.70	12.60	3.95	2.30	2.00	5.00	3.95
7	2.60	2.40	2.10	2.10	2.60	3.85	12.20	3.75	2.30	2.00	4.75	3.85
8	2.50	2.25	2.00	2.10	2.60	7.40	10.10	3.60	2.30	1.90	4.35	3.85
9	2.50	2.25	2.20	2.10	2.55	10.30	9.00	3.60	2.20	1.90	4.10	3.95
10	2.50	2.40	2.05	2.10	3.15	9.45	8.40	3.50	2.20	1.95	3.85	4.25
11	2.50	2.40	2.00	2.05	5.10	7.95	8.35	3.40	2.15	1.95	3.70	6.45
12	2.50	2.30	1.95	1.95	5.25	7.40	7.50	3.30	2.10	1.90	3.60	9.75
13	2.50	2.30	1.90	1.80	5.75	7.10	6.95	3.20	2.10	1.90	3.50	8.60
14	2.50	2.30	2.00	1.90	4.70	6.60	6.50	3.15	2.10	1.90	3.40	7.55
15	2.60	2.30	2.00	5.90	4.05	6.30	6.25	3.10	2.10	1.90	3.30	6.70
16	2.45	2.30	2.00	2.75	4.20	6.60	5.90	3.00	2.05	1.90	3.20	6.00
17	2.40	2.40	2.00	2.55	4.30	10.00	5.70	3.00	2.10	1.90	3.15	5.80
18	2.40	2.40	2.00	2.60	6.20	6.55	5.65	2.95	2.15	1.90	3.10	5.70
19	2.45	2.40	2.10	2.45	5.55	18.50	5.40	2.90	2.10	1.90	3.30	5.15
20	2.50	2.35	1.95	2.40	4.80	20.70	5.20	2.80	2.10	1.90	5.90	4.95
21	2.50	2.30	1.90	2.35	4.20	18.05	5.15	2.80	2.30	1.90	19.85	5.85
22	2.55	2.30	1.90	2.30	4.10	10.25	5.00	2.70	2.65	1.90	21.85	9.40
23	2.40	2.30	1.80	2.30	3.75	9.10	5.30	2.70	2.45	1.90	11.85	6.55
24	2.50	2.30	1.90	2.20	4.50	8.20	9.95	2.70	2.40	1.90	8.90	6.20
25	2.50	2.30	1.80	2.20	6.40	7.35	9.00	2.60	2.30	1.95	8.40	6.10
26	2.40	2.30	1.90	2.15	5.85	6.85	8.30	2.55	2.40	2.25	7.25	5.75
27	2.40	2.30	1.90	2.20	5.45	6.30	7.25	2.50	2.40	2.55	6.70	5.50
28	2.40	2.20	1.90	2.20	5.05	6 10	6.60	2.50	2.35	2.50	6.20	5.05
29	2.35	.....	1.85	2.10	5.00	a9.00	6.10	2.50	2.20	9.15	5.60	4.95
30	2.40	.....	1.80	2.05	7.25	a12.00	5.90	2.50	.....	11.00	5.45	4.85
31	2.30	.....	1.80	.....	6.50	.....	5.70	2.50	.....	8.30	.....	4.70

a Estimated.

BRAZOS RIVER AT LEWIS, TEXAS.

This station, established by Thomas U. Taylor February 22, 1898, is at the International and Great Northern Railroad bridge about 1¼ miles southwest of the town of Lewis, Texas, and about 75 miles below the station at Waco. After the establishment of the Waco station the one at Lewis was not of much importance, and was discontinued February 25, 1899. No measurements of discharge were made here during 1899.

Daily gage height, in feet, of Brazos River at Lewis, Texas, for 1899.

Day.	Jan.	Feb.	Day.	Jan.	Feb.	Day.	Jan.	Feb.	Day.	Jan.	Feb.
1	4.40	4.30	9	4.50	4.20	17	4.60	4.20	25	4.30	4.20
2	4.40	4.25	10	4.60	4.20	18	4.45	4.20	26	4.25	.....
3	4.35	4.20	11	4.80	4.20	19	4.40	4.20	27	4.20	.....
4	4.30	4.20	12	5.15	4.20	20	4.40	4.20	28	4.15	.....
5	4.40	4.20	13	5.45	4.20	21	4.40	4.20	29	4.05	.....
6	4.70	4.10	14	6.25	4.20	22	4.35	4.20	30	4.15	.....
7	4.55	4.15	15	5.10	4.20	23	4.25	4.20	31	4.20	.....
8	4.50	4.20	16	4.85	4.20	24	4.20	4.20			

Station discontinued February 25.

COLORADO RIVER AT AUSTIN, TEXAS.

This river drains a large area in central Texas. It rises in the extreme western portion of the State, within a few miles of the western boundary of New Mexico, and flows in a general southeasterly direction, emptying into the Gulf of Mexico in Matagorda County. Its head-water tributaries drain the country immediately south of the Brazos River. Llano Creek is a tributary of Colorado River and empties into it 85 miles above Austin. On March 14, 1899, this stream was measured one-half mile west of the station at Llano, Texas, and showed a discharge of 76 second-feet; a second measurement was made below on this creek, 200 yards above its junction with the Colorado River at Kingsland, on the same date, which also showed a discharge of 76 second-feet. On March 13 the main Colorado River, at a short distance below the wagon bridge near Marble Falls, Texas, showed a discharge of 197 second-feet. The river was also measured four times at the head of Lake McDonald, about 20 miles above Austin. On January 31 it showed a discharge of 210 second-feet; on October 3 the discharge was 134 second-feet; on October 4 the discharge was also 134 second-feet; and on the same date, at another section near by, the discharge was 136 second-feet. On March 15 two measurements were made at the power house at the Austin dam. The first measurement was in the fore bay, and showed a discharge of 206 second-feet; immediately afterwards the tailrace was measured and showed a discharge of 233 second-feet. The station maintained during 1899 is located at the Congress avenue bridge, south of the city of Austin. The gage rod is a vertical timber attached to a bath house near by. The bench mark is on the first flange above the cribwork of the north pier of the highway bridge, and is 4.78 feet above the zero of the gage. The following measurements of discharge were made by Thomas U. Taylor during 1899:

March 17, gage height, 1.70 feet; discharge, 267 second-feet.
March 31, gage height, 1.50 feet; discharge, 170 second-feet.
November 10, gage height, 1.71 feet; discharge, 476 second-feet.
November 16, gage height, 1.50 feet; discharge, 386 second-feet.
November 28, gage height, 2.36 feet; discharge, 1,156 second-feet.
December 5, gage height, 2.02 feet; discharge, 686 second-feet.

Daily gage height, in feet, of Colorado River at Austin, Texas, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.90	2.00	1.85	1.45	2.05	3.60	3.85	3.10	1.45	1.05	2.80	2.65
2	1.85	1.95	1.85	1.45	2.05	3.20	3.35	2.45	1.45	1.05	2.35	2.50
3	1.85	1.90	1.75	1.45	2.00	2.95	3.55	2.30	1.45	.90	2.10	2.50
4	1.95	2.05	1.85	1.45	2.10	3.55	3.50	1.95	1.45	.85	2.10	2.20
5	1.95	1.95	1.85	1.55	2.00	3.15	3.65	1.80	1.45	.90	1.95	2.05
6	1.95	1.90	1.85	1.50	2.05	2.85	3.45	1.70	1.40	.90	1.95	2.05
7	1.85	1.90	1.90	1.50	1.95	11.35	3.15	1.75	1.40	.85	2.00	2.05
8	1.95	1.85	1.80	1.45	1.85	21.05	2.95	1.75	1.40	.80	1.90	2.40
9	1.95	1.90	1.85	1.45	1.95	17.60	3.60	1.65	1.40	.85	1.80	2.75
10	1.95	1.90	1.80	1.45	2.00	14.75	3.25	1.65	1.35	.90	1.75	3.45
11	1.95	1.90	1.75	1.45	2.00	9.00	3.00	1.65	1.35	.90	1.70	6.40
12	2.05	2.10	1.75	1.45	4.10	5.30	2.80	1.55	1.35	.90	1.65	5.35
13	1.95	1.95	1.75	1.50	7.95	4.45	2.65	1.55	1.35	.90	1.60	4.30
14	1.90	1.80	1.75	1.55	7.10	4.10	2.50	1.55	1.35	.90	1.65	3.70
15	1.85	1.75	1.80	1.50	5.30	3.60	2.30	1.55	1.35	.90	1.60	3.35
16	1.90	1.80	1.80	1.50	4.55	3.75	2.15	1.55	1.35	.90	1.55	3.05
17	1.90	1.85	1.75	1.55	3.85	4.40	2.05	1.55	1.35	.85	1.50	2.85
18	1.95	1.80	1.75	1.65	3.40	5.90	2.00	1.55	1.35	.95	1.45	2.70
19	1.95	1.75	1.75	1.80	3.20	6.60	2.00	1.55	1.30	1.45	1.75	2.60
20	1.90	1.75	1.70	1.90	3.00	6.15	2.00	1.65	1.30	.95	2.00	2.65
21	1.90	1.75	1.65	3.95	2.75	4.90	1.90	1.55	1.25	.90	5.35	2.75
22	1.90	1.75	1.65	3.80	2.45	6.00	1.85	1.55	1.25	.90	6.35	2.90
23	1.90	1.85	1.60	3.45	4.20	5.15	1.80	1.55	1.15	.90	4.55	4.05
24	1.90	1.90	1.60	3.05	4.05	4.15	1.80	1.55	1.15	1.40	5.65	3.90
25	1.95	1.85	1.60	2.85	4.75	3.75	1.75	1.55	1.10	1.35	3.00	3.40
26	1.90	1.85	1.60	2.65	4.50	3.45	2.35	1.55	1.15	1.45	2.65	3.05
27	1.90	1.85	1.60	2.55	5.05	3.15	2.45	1.55	1.15	1.55	2.55	2.85
28	1.90	1.75	1.60	2.45	4.85	2.95	2.20	1.55	1.15	2.30	2.35	2.75
29	1.90	.....	1.55	2.35	4.10	2.85	3.30	1.55	1.15	3.35	2.35	2.70
30	1.90	.....	1.45	2.25	3.70	2.75	4.25	1.55	1.05	2.90	2.95	2.55
31	1.95	.....	1.50	.....	3.35	.....	3.60	1.55	.....	3.10	.....	.....

GUADALUPE RIVER AT NEW BRAUNFELS, TEXAS.

This river drains a small area in central Texas. Its source is in Kerr County, and it has a general southeasterly direction, emptying into the Gulf of Mexico in Calhoun County. At New Braunfels it receives Comal River, which is the principal source of supply for the upper Guadalupe. Comal River is simply the outlet of a series of large springs near New Braunfels and is only about 3 miles long. These springs maintain a very constant flow throughout the entire year. Comal River is described in Bulletin 140, page 84. The gaging station at New Braunfels is about 1 mile east of the town, near the highway bridge, and below the International and Great Northern Railroad bridge, and was established March 13, 1898. It is located below the mouth of Comal River, and hence includes the flood waters of the main Guadalupe besides the very equable discharge of Comal River. Two measurements of discharge were made by Thomas U. Taylor during 1899: The first, on March 16, with a gage height of 1.80, showed a total discharge of the two channels of 358 second-feet; the second one, on December 23, with a gage height of 2.70 feet, gave a discharge of 797 second-feet.

Daily gage height, in feet, of Guadalupe River at New Braunfels, Texas, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.80	1.80	1.80	1.80	1.80	1.90	3.65	2.00	1.80	1.70	2.40	2.00
2	1.80	1.80	1.80	1.80	1.80	1.90	2.65	2.00	1.80	1.70	2.30	2.00
3	1.80	1.80	1.80	1.80	1.80	1.85	2.45	1.90	1.80	1.70	2.05	2.00
4	1.80	1.80	1.80	1.80	2.15	1.80	2.35	1.90	1.80	1.70	2.00	1.90
5	1.80	1.80	1.80	1.85	2.05	1.80	2.60	1.90	1.80	1.70	2.00	1.90
6	1.80	1.80	1.80	1.90	1.85	3.85	2.60	1.90	1.80	1.70	2.00	1.90
7	1.80	1.80	1.80	1.80	1.80	3.25	2.50	1.90	1.80	1.70	1.90	1.95
8	1.80	1.80	1.80	1.80	1.80	16.00	2.45	1.90	1.80	1.70	1.90	2.05
9	1.80	1.80	1.80	1.80	1.80	8.00	2.30	1.85	1.80	1.70	1.90	2.60
10	1.80	1.80	1.80	1.80	1.80	4.20	2.30	1.80	1.80	1.70	1.90	2.30
11	1.80	1.80	1.80	1.80	2.65	3.55	2.25	1.80	1.80	1.70	1.90	2.20
12	1.80	1.80	1.80	1.80	2.10	3.10	2.20	1.80	1.80	1.70	1.90	2.20
13	1.80	1.80	1.80	1.80	1.95	3.45	2.10	1.80	1.80	1.70	1.60	2.10
14	1.80	1.80	1.80	1.80	1.90	3.00	2.10	1.80	1.80	1.70	1.90	2.10
15	1.80	1.80	1.80	1.85	1.90	2.75	2.10	1.80	1.80	1.70	1.90	2.00
16	1.80	1.80	1.80	1.85	1.90	2.55	2.10	1.80	1.80	1.70	1.90	2.00
17	1.80	1.80	1.80	1.80	1.90	4.45	2.00	1.80	1.80	1.70	1.80	2.00
18	1.80	1.80	1.80	1.80	1.90	3.05	2.00	1.80	1.80	1.70	1.80	2.10
19	1.80	1.80	1.80	1.80	1.80	3.15	2.00	1.80	1.80	1.70	1.90	2.25
20	1.80	1.80	1.80	1.95	1.80	2.85	1.90	1.80	1.80	1.70	2.15	2.40
21	1.80	1.80	1.80	2.45	1.80	2.60	1.90	1.80	1.80	1.90	2.10	2.65
22	1.80	1.80	1.80	2.20	1.80	2.50	1.90	1.80	1.80	2.00	2.10	2.80
23	1.80	1.80	1.80	2.00	4.20	2.45	1.90	1.80	1.80	2.00	2.30	2.70
24	1.80	1.80	1.80	2.00	2.90	2.40	1.90	1.80	1.80	2.00	2.30	2.55
25	1.80	1.80	1.80	2.00	2.50	2.40	2.00	1.80	1.80	2.00	2.30	2.40
26	1.80	1.80	1.80	2.00	2.30	2.30	2.00	1.80	1.75	2.00	2.10	2.30
27	1.80	1.80	1.80	1.90	2.05	2.20	2.00	1.80	1.70	2.15	2.10	2.30
28	1.80	1.80	1.80	1.80	2.00	2.20	4.50	1.80	1.70	6.15	2.00	2.20
29	1.80	.....	1.80	1.80	2.00	2.15	3.35	1.80	1.70	3.30	2.00	2.20
30	1.80	.....	1.80	1.80	2.00	2.10	2.20	1.80	1.70	2.70	2.00	2.20
31	1.80	.....	1.80	.....	1.90	.....	2.00	1.80	.....	2.45	.....	.....

LEONA RIVER AT UVALDE, TEXAS.

In former years there was located in the southern suburbs of Uvalde a large spring with constant flow, known as "Leona spring." This spring was dry but once between 1870 and 1893, viz, in 1885. It soon revived, however, and continued flowing up to 1893, when the discharge stopped, and no water has issued from it since that date. The water in the wells in the vicinity in 1884 was 25 feet below the surface of the ground, but in 1899 the level was about 50 feet below the surface. A pumping station was located on the banks of Leona River, near Leona spring, in 1893, but after one or two years the river failed to such an extent that the entire pumping plant was moved to within 150 yards of the court-house at Uvalde. At the new station a 15 by 15 foot pit was excavated 24 feet deep, and the pumps were placed at the bottom of this pit, and then a well 4 by 7 feet square was sunk from this level to a depth of 16 feet, out of which the water was pumped into a standpipe. The water at first rose in this well to within 35 feet of the ground surface. In December, 1897, it was noticed that the supply was failing, and this continued until May, 1898, when a second pit, 10 by 10 feet, and 9 feet deep, was excavated on the southwest side of the first pit, and the well was also lowered until its bottom was 63 feet below the ground surface; when the pumps were finally lowered, their new position was 33 feet below the surface. In January, 1899, it was found necessary to sink three small drill wells in the bottom of the main pump well to a depth of

30 to 35 feet, reaching a total depth of 98 feet from the surface of the ground.

Leona River, in 1895, was found by Mr. Cyrus C. Babb to be dry under the railroad bridge, but at the crossing 1½ miles south of the town a discharge of 11 second-feet was found. The river ceased flowing at this crossing in January, 1898. About June 15, 1899, heavy rains fell over Uvalde and Kinney counties, raising the Leona River to a flowing depth of 6 to 8 feet. Notwithstanding this, on June 28, 1899, when visited by Thomas U. Taylor, the river was dry at the crossing above referred to. The bed of the stream was followed to the head of the upper irrigation ditch about 4 miles below the town of Uvalde, but no flowing water was found. The only irrigation along Leona River in 1899 was done through the agency of a steam pump 10 or 12 miles below Uvalde.

LAS MORAS SPRING, NEAR BRACKETTVILLE, TEXAS.

This spring is located at Fort Clark, near Brackettville, 10 miles distant from Spofford, on the Southern Pacific Railroad. The discharge from this spring was measured by Prof. Thomas U. Taylor on June 30, 1899, when 60 second-feet was found. A measurement on December 24, 1895, near the same point, by Cyrus C. Babb, showed a discharge of 21 second-feet.

SAN FELIPE SPRINGS, NEAR DEL RIO, TEXAS.

San Felipe Creek has its source in four large springs, the upper one being 2 miles above the railroad bridge near Del Rio, the others being within about 200 yards of the bridge. On June 29, 1899, the creek was measured by Prof. Thomas U. Taylor, at a point about 200 yards below the railroad bridge, and a discharge of 84 second-feet was found. Madre ditch diverts water from one of these springs above the point of measurement, and on June 29 its discharge was found to be 29 second-feet. Previous measurements at this locality will be found in Bulletin 140, page 85.

RIO GRANDE AT DEL NORTE, COLORADO.

This river has its source in the Continental Divide in southern Colorado. Its general course is easterly through its mountainous collecting area until San Luis Park is reached, when it gradually takes a southeasterly course, and then just before crossing the State line into New Mexico it bends southward and continues this general course throughout New Mexico. The station is located about 2 miles above the town of Del Norte, Colorado, well above most of the irrigation ditches which divert water from this river. The gage consists of an inclined 2 by 6 inch plank fastened to a post driven into the right bank of the river. Bench mark No. 1 is a large nail in the root of a tree 15 feet northeast of the end of the cable on the left bank of the

river and is 7.54 feet above gage datum. Bench mark No. 2 is a large nail in the root of a tree 25 feet northwest of the end of the inclined gage, and is also 7.54 feet above gage datum. While the banks are not high, the river has never been known to overflow. The current is swift; the bed is composed of small stone, and has not materially changed during the last year. Discharge measurements are made from a box suspended from a five-eighths inch wire cable fastened to trees on each side of the river. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 247; 1897, Nineteenth Annual Report, Part IV, page 383; 1898, Twentieth Annual Report, Part IV, page 360. The following discharge measurements were made by A. L. Fellows during 1899:

April 25, gage height, 2.42 feet; discharge, 1,004 second-feet.
May 24, gage height, 2.92 feet; discharge, 1,480 second-feet.
June 29, gage height, 2.10 feet; discharge, 734 second-feet.
August 21, gage height, 1.58 feet; discharge, 387 second-feet.

Daily gage height, in feet, of Rio Grande at Del Norte, Colorado, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1				1.62	1.90	2.94	2.00	2.24	1.46			
2												1.96
3				1.48	1.82	2.62	2.12	2.20	1.50			
4		2.64	2.82								1.64	
5				1.40	1.86	2.44	1.98	2.64	1.48			
6												
7	2.76			1.40	1.96	2.50	2.12	2.42	1.40	1.50		
8												
9				1.52	2.16	2.68	1.94	2.12	1.40			2.00
10												
11		2.60	2.66	1.70	3.62	2.82	1.90	2.00	1.40		1.60	
12												
13				1.84	3.54	2.90	1.80	1.84	1.38			
14	2.74									1.90		
15				1.92	3.20	2.62	1.86	1.76	2.12			
16												2.30
17				2.04	3.18	2.50	1.86	1.82	1.86			
18		2.46	2.04								1.62	
19				2.10	3.14	2.38	2.74	1.70	1.64			
20												
21	2.68			2.14	3.02	2.32	2.14	1.60	1.58	1.80		
22												
23				2.30	2.84	2.20	2.02	1.60	1.52			2.04
24												
25		2.48	1.96	2.46	3.04	2.10	1.84	1.54	1.48		2.04	
26												
27				2.28	2.96	2.48	1.84	1.50	1.44			
28	2.84									1.72		
29				2.24	2.84	2.10	2.00	1.48	1.42			
30									1.42			2.12
31				1.64		2.90		2.24	1.42			

CONEJOS RIVER AT LOS MOGOTES, COLORADO.

This stream rises on the eastern slope of the mountain range which forms the western line of Conejos County, in southern Colorado. It flows southeasterly, and then bending at the town of Conejos flows in a general northeasterly direction, entering the Rio Grande below the mouth of Trinchera Creek. The gage rod, established by A. L. Fellows August 25, 1899, was at first located at a wagon bridge 10 miles above the town of Conejos, but owing to the fact that it was destroyed

at this point, it was later moved to a point about 500 yards below. It is here attached to the pier projecting into the river near the house occupied by Gustav Timm, a ranchman who has acted as observer. The channel is fairly good, being of gravel and not particularly liable to either change or overflow. Owing to the removal of the gage it will not be possible to make a rating table for 1899. Two measurements of discharge were made at this point in 1899 by A. L. Fellows: The first, on August 25, at a gage height of 1.00 foot, showed a discharge of 76 second-feet; the second measurement, on November 28, at a gage height of 2.20 feet, showed a discharge of 70 second-feet.

Daily gage height, in feet, of Conejos River at Los Mogotes, Colorado, for 1899.

Day.	Sept.	Oct.	Nov.	Day.	Sept.	Oct.	Nov.	Day.	Sept.	Oct.	Nov.
1	.95	1.02	1.15	12	.98	1.20	1.57	23	1.18	1.30	1.50
2	.92	1.05	1.12	13	.95	1.38	1.57	24	1.15	1.28	1.48
3	.92	1.10	1.12	14	.98	1.32	1.57	25	1.10	1.25	1.40
4	.92	1.12	1.10	15	2.00	1.25	1.57	26	1.05	1.25	1.55
5	.90	1.10	a 1.55	16	1.75	1.22	1.65	27	1.05	1.15	1.90
6	.90	1.07	1.57	17	1.65	1.25	1.70	28	1.05	1.20	2.20
7	.87	1.07	1.57	18	1.50	1.28	1.70	29	1.05	1.18	2.10
8	.87	1.05	1.57	19	1.30	1.25	1.70	30	1.05	1.15	1.60
9	1.02	1.05	1.57	20	1.22	1.20	1.60	31	.....	1.15	.....
10	1.05	1.02	1.57	21	1.22	1.30	1.58				
11	1.00	1.00	1.57	22	1.20	1.32	1.55				

a Gage moved to a point near house of Gustav Timm.

RIO GRANDE AT CENICERO, COLORADO.

The Rio Grande for a number of years has been dry during the summer after passing through San Luis Park, due to the diversion of water above. On August 20 the river 6 miles below Alamosa, Colorado, was carrying 17 second-feet, and on the 23d of the same month, at a point one-half mile above Alamosa, the discharge was found to be 10 second-feet. Just before it crosses the State line into New Mexico it enters the canyon, and in order to obtain the amount of water passing out of the State, a station was located on June 28, 1899, by A. L. Fellows, at the State bridge across the Rio Grande, at a point about 4 miles west of Eastdale, Colorado. The station is favorably located for the purpose, the cross section being fairly uniform, the channel regular and not liable to overflow. The gage consists of two rods, one for low stages, fastened to a rock near the shore; the upper section is fastened to the lower side of the middle pier of the bridge. The observer is Roman Mondragon. The following measurements of discharge were made by A. L. Fellows in 1899:

June 28, gage height, 0.90 foot; discharge, 20 second-feet.
August 24, gage height, 1 foot; discharge, 31 second-feet.
November 28, gage height, 1.80 feet; discharge, 297 second-feet.

Daily gage height, in feet, of Rio Grande at Cenicero, Colorado, for 1899.

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1		0.78	1.00	1.00	1.30	1.50	1.80
2		.90	1.00	1.00	1.30	1.50	1.80
3		.88	.90	1.00	1.20	1.60	1.80
4		.90	.90	1.00	1.40	1.60	1.70
5		1.00	1.40	1.00	1.30	1.60	1.60
6		.90	1.40	1.00	1.20	1.60	1.50
7		.90	1.30	1.00	1.20	1.60	1.60
8		.90	1.40	1.00	1.20	1.70	1.60
9		.90	1.40	1.00	1.30	1.70	1.70
10		.85	1.30	1.00	1.30	1.80	1.60
11		.80	1.30	1.00	1.40	1.70	1.60
12		.80	1.30	1.00	1.30	1.70	1.70
13		.85	1.30	1.10	1.30	1.70	1.70
14		.90	1.20	1.10	1.20	1.80	1.80
15		1.00	1.10	1.60	1.30	1.80	1.90
16		1.00	1.00	2.10	1.30	1.70	2.00
17		1.00	1.00	2.00	1.40	1.70	2.00
18		.98	1.00	1.40	1.40	1.70	2.00
19		1.00	1.00	1.50	1.40	1.70	2.00
20		1.00	.90	1.50	1.40	1.70	2.00
21		1.02	.90	1.50	1.40	1.70	2.00
22		1.08	1.00	1.40	1.40	1.80	2.00
23		1.50	1.00	1.40	1.40	1.80	2.00
24		1.50	1.00	1.40	1.40	1.80	2.00
25		1.35	.95	1.30	1.50	1.80	2.00
26		1.30	.90	1.30	1.50	1.80	2.00
27		1.20	.90	1.30	1.50	1.80	2.00
28	0.90	1.10	1.00	1.30	1.50	1.80	2.00
29	.90	1.10	1.00	1.30	1.50	1.80	2.00
30	.80	1.10	1.00	1.30	1.50	1.80	2.00
31		1.00	1.00		1.50		2.00

RIO GRANDE AT EMBUDO, NEW MEXICO.

Rio Grande enters the canyon some distance above where it crosses the New Mexico and Colorado line, and continues southward for some distance below Embudo. It receives a number of important tributaries from either side through this section of its course, which contribute to its discharge; and although in recent years the river is dry in the vicinity of Alamosa, Colorado, there is a constant flow at Embudo, New Mexico. The station at this point, established in 1889, is located about 300 feet east of the railroad station at Embudo. The gage is inclined, and consists of a timber fastened to posts driven into the bank of the river. Bench mark No. 1 is a rock near the end of the cable, left bank, marked "B. M." with white paint, and is 20.66 feet above gage datum. Bench mark No. 2 is a rock 100 feet above the cable, left bank, similarly marked, and is 18.79 feet above gage datum. Bench mark No. 3 is a notch cut in the southeastern corner of the station, 2 feet above the platform, and is 30.48 feet above gage datum. The left bank is steep, and the right has a gentle slope. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 251; 1897, Nineteenth Annual Report, Part IV, page 385; 1889 to 1898, Twentieth Annual Report, Part IV, page 366. The following measurements of discharge were made by P. E. Harroun during 1899:

April 7, gage height, 8.20 feet; discharge, 710 second-feet.
April 20, gage height, 9.50 feet; discharge, 1,627 second-feet.
May 4, gage height, 8.60 feet; discharge, 967 second-feet.
May 30, gage height, 8.10 feet; discharge, 745 second-feet.
September 4, gage height, 7 feet; discharge, 183 second-feet.
October 27, gage height, 7.58 feet; discharge, 412 second-feet.

Daily gage height, in feet, of Rio Grande at Embudo, New Mexico, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	7.50	7.60	7.70	8.40	9.20	7.90	7.20	7.20	7.00	7.30	7.60	7.85
2	7.60	7.60	7.70	8.30	9.00	7.85	7.20	7.25	7.00	7.30	7.60	7.85
3	7.60	7.60	7.80	8.30	8.80	7.80	7.15	7.20	7.00	7.35	7.60	7.80
4	7.60	7.70	7.80	8.30	8.60	7.80	7.10	7.20	7.00	7.40	7.60	7.80
5	7.60	7.70	7.85	8.20	8.45	7.80	7.10	7.30	7.00	7.40	7.65	8.00
6	7.70	7.70	7.90	8.20	8.25	7.60	7.10	7.25	7.00	7.40	7.70	7.85
7	7.85	7.70	8.00	8.20	8.20	7.35	7.10	7.20	7.00	7.40	7.75	7.70
8	7.90	7.80	8.05	8.10	8.20	7.00	7.10	7.20	7.10	7.40	7.80	7.70
9	7.90	7.80	8.15	8.10	8.20	6.90	7.10	7.20	7.10	7.40	7.80	7.80
10	7.90	7.85	8.20	8.10	8.20	6.85	7.10	7.30	7.10	7.40	7.80	8.00
11	7.90	7.90	8.20	8.10	8.20	6.70	7.05	7.25	7.10	7.40	7.80	7.60
12	7.90	7.80	8.25	8.20	8.30	6.60	7.00	7.20	7.10	7.40	7.80	7.60
13	7.90	7.90	8.30	8.50	8.65	6.70	7.00	7.20	7.15	7.40	7.80	7.60
14	7.80	7.80	8.35	8.65	8.80	6.95	7.10	7.20	7.20	7.40	7.80	7.70
15	7.80	7.80	8.50	8.80	9.00	7.00	7.25	7.25	a 7.30	7.50	7.85	7.60
16	7.70	7.80	8.65	8.80	9.10	7.00	7.40	7.30	8.15	7.50	7.90	7.60
17	7.70	7.80	8.70	8.85	9.20	7.00	7.60	7.30	7.90	7.50	7.90	7.70
18	7.70	7.70	8.70	9.05	9.20	7.00	7.60	7.15	7.85	7.50	7.90	7.70
19	7.70	7.70	8.70	9.35	9.15	7.00	8.10	7.10	7.80	7.50	7.90	7.70
20	7.70	7.70	8.65	9.35	9.00	7.00	7.90	7.10	7.65	7.50	7.90	7.70
21	7.70	7.70	8.60	9.30	9.00	7.00	7.60	7.10	7.60	7.50	7.95	7.70
22	7.70	7.70	8.45	9.25	8.80	7.00	7.60	7.10	7.50	7.50	8.00	7.70
23	7.70	7.70	8.40	9.20	8.75	7.00	7.55	7.00	7.50	7.50	8.00	7.70
24	7.70	7.70	8.30	9.20	8.50	7.10	7.50	7.00	7.50	7.50	8.00	7.70
25	7.60	7.70	8.30	9.30	8.20	7.10	7.45	7.00	7.40	7.50	8.10	7.70
26	7.60	7.70	8.30	9.40	8.20	7.10	7.35	7.00	7.40	7.50	8.10	7.70
27	7.60	7.70	8.30	9.40	8.10	7.00	7.20	7.00	7.30	7.50	8.00	7.70
28	7.60	7.70	8.35	9.30	8.10	7.15	7.15	7.00	7.30	7.50	8.00	7.70
29	7.60	.....	8.40	9.20	8.10	7.20	7.10	7.00	7.30	7.60	7.90	7.70
30	7.60	.....	8.35	9.20	8.00	7.20	7.10	7.00	7.30	7.60	7.90	7.70
31	7.60	.....	8.40	.....	8.00	.....	7.20	7.00	.....	7.60	.....	7.70

a Began to rise at 4.30 p. m.; maximum, 8.3 feet, at 6 p. m.

RIO GRANDE AT RIO GRANDE, NEW MEXICO.

Three miles below Embudo the river emerges into Espanola Valley, through which it continues for a few miles and then enters White Rock Canyon, flowing through that canyon for 30 miles. At the lower end of this canyon the river emerges into Albuquerque Valley, and so continues down to about Socorro. This valley averages from 1 to 3 miles in width, and has been irrigated for a great many years by the Mexican settlers. Their primitive methods of irrigation are very wasteful of the waters, so that the duty of water in this section, about 17 acres per second-foot, is not as high as it might be. During the last few years, however, a number of important and modern irrigation systems have been planned and built in the vicinity of Albuquerque. The gaging station, established February 3, 1895, is located about one-fourth of a mile above the railroad station of Rio Grande, New Mexico, and at the head of White Rock Canyon. The gage is inclined, and consists of timbers fastened to piles and wired to a solid rock. The bench mark is the top of the bowlder to which the upper portion of the gage is fastened, and is 17.815 feet above gage datum. Measurements are made from a car suspended from a cable above the rod. The bed of the stream is rocky and is confined between high banks. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 254; 1897, Nineteenth Annual Report, Part IV, page 386; 1898,

Twentieth Annual Report, Part IV, page 370. Three measurements of discharge were made at this point by P. E. Harroun during 1899: The first one, on April 6, at a gage height of 5.90 feet, gave a discharge of 978 second-feet; the second, on September 2, at a gage height of 3.70 feet, gave a discharge of 110 second-feet; the third measurement, October 24, at a gage height of 5.15 feet, gave a discharge of 482 second-feet.

Daily gage height, in feet, of Rio Grande at Rio Grande, New Mexico, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.65	5.40	5.65	6.20	7.15	5.60	4.20	5.00	3.60	4.70	5.30	5.65
2	4.65	5.35	6.00	6.20	7.15	5.55	4.20	4.80	3.60	4.70	5.25	5.60
3	4.65	5.35	5.90	6.05	6.95	5.45	4.30	4.70	3.60	4.70	5.30	5.60
4	4.75	5.15	5.80	6.15	6.75	5.45	4.30	6.75	3.65	4.85	5.40	5.60
5	4.85	5.30	5.80	6.10	6.60	5.45	4.10	5.50	3.60	5.10	5.40	5.35
6	4.75	5.20	5.85	5.90	6.50	5.35	4.00	5.00	3.60	5.05	5.45	5.00
7	4.85	5.30	5.85	5.85	6.45	5.25	4.00	6.35	3.55	5.05	5.50	5.25
8	4.95	5.30	5.90	6.05	6.35	5.20	3.90	5.45	4.00	5.00	5.55	5.40
9	5.10	5.45	6.15	5.95	6.35	5.05	4.40	5.45	4.25	4.95	5.55	5.65
10	5.00	5.45	6.05	6.05	6.30	5.40	4.20	4.80	4.75	4.90	5.55	5.45
11	4.95	5.45	6.25	6.30	6.30	5.10	4.20	4.75	4.95	4.85	5.60	5.25
12	5.00	5.35	6.25	6.45	6.45	5.05	4.20	4.65	4.35	4.85	5.55	5.15
13	4.95	5.20	6.20	6.65	6.40	5.00	4.00	4.60	4.30	4.85	5.55	5.40
14	5.00	5.75	6.20	6.95	6.65	4.90	4.40	4.55	4.30	4.80	5.55	5.40
15	5.05	5.50	6.25	7.30	7.15	4.85	4.55	4.40	a9.30	4.80	5.90	5.15
16	5.05	5.40	5.85	7.20	7.35	4.60	5.00	4.35	9.40	5.00	5.70	4.85
17	5.00	5.50	6.15	7.65	7.40	4.65	5.05	4.30	6.55	5.00	5.75	5.10
18	5.00	5.45	6.40	8.15	7.15	4.50	7.80	4.15	5.85	5.05	5.70	5.40
19	5.00	5.50	6.30	8.30	6.90	4.45	6.80	4.20	5.45	4.95	5.70	5.65
20	5.05	5.45	6.35	8.30	6.75	4.40	6.30	4.15	5.25	5.05	5.70	5.55
21	5.05	5.50	6.30	7.95	6.75	4.30	5.70	4.10	5.15	5.10	5.70	5.40
22	5.00	5.50	6.25	7.70	6.75	4.20	5.30	4.00	5.25	5.15	5.70	5.30
23	5.00	5.50	6.20	7.75	6.40	4.20	5.30	3.90	5.00	5.15	5.80	5.45
24	5.00	5.55	6.15	7.85	6.25	4.30	5.15	3.75	5.05	5.15	5.80	5.50
25	5.05	5.80	6.20	7.90	6.10	4.40	5.25	3.85	4.95	5.20	5.80	5.45
26	5.10	5.50	6.45	8.05	6.10	4.65	5.20	3.80	4.85	5.20	5.75	5.45
27	5.20	5.50	6.65	7.95	5.95	4.50	5.30	3.70	4.85	5.30	5.75	5.40
28	5.25	5.65	6.60	7.75	6.00	4.40	5.35	3.75	4.75	5.30	5.75	5.40
29	5.25	.....	6.55	7.50	5.85	4.20	5.00	3.70	4.75	5.30	5.70	5.45
30	5.35	.....	6.45	7.15	5.80	4.35	5.05	3.60	4.65	5.25	5.70	5.50
31	5.40	.....	6.40	.....	5.70	.....	6.05	3.60	.....	5.25	.....	5.65

a 10 at 7 a. m.

RIO GRANDE AT SAN MARCIAL, NEW MEXICO.

The fifth gaging station on the main stream, continuing downward, is at San Marcial. It was established January 29, 1895, and is located at the railroad bridge one-half mile south of the town. The wire gage is attached to the guard rail of the bridge, south span, lower side. Bench mark No. 1 is the top of the capstone on which the bridge truss rests, and is at an elevation of 15 feet above gage datum; bench mark No. 2 is the top of the extension of the pier to which the old vertical gage was fastened, and is at an elevation of 13 feet above gage datum. The channel is sandy and shifting. A number of bridge piers interfere with the current to a certain extent, but not with the observed gage heights or discharge measurements. Results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 257; 1897, Nineteenth Annual Report, Part IV, page 387; 1898, Twentieth Annual Report, Part IV, page 371. The following discharge measurements were made by P. E. Harroun during 1899:

Measurements of Rio Grande at San Marcial, New Mexico.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Sec. feet.*	1899.	*Feet.*	*Sec. feet.*
Apr. 8	7.80	715	May 17	6.50	199
Apr. 19	7.30	660	Sept. 22	5.30	112
Apr. 25	7.70	1,609	Oct. 12	4.40	6
May 2	7.60	1,403	Dec. 17	6.20	263

Daily gage height, in feet, of Rio Grande at San Marcial, New Mexico, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	6.95	6.90	6.70	7.00	7.70	6.00	.....	6.00	.....	.....	5.00	6.50
2	6.75	6.85	6.70	7.15	7.65	5.80	.....	5.80	.....	.....	5.00	6.50
3	6.50	6.70	6.60	7.30	7.50	5.70	.....	5.60	.....	.....	5.10	6.50
4	6.60	6.70	6.50	7.10	7.40	5.60	.....	5.40	.....	.....	5.10	6.55
5	6.55	6.60	6.50	7.00	7.40	5.40	.....	5.65	.....	.....	5.20	6.55
6	6.60	6.50	6.70	6.90	7.30	5.25	.....	6.80	.....	.....	5.20	6.55
7	6.60	5.10	6.70	7.20	7.20	5.00	.....	7.15	.....	.....	5.30	6.55
8	6.75	4.50	6.50	7.00	7.20	.....	.....	7.55	.....	.....	5.30	6.60
9	6.55	4.50	6.80	6.90	7.20	.....	.....	6.95	5.35	.....	5.40	6.60
10	6.50	6.95	6.50	6.80	7.10	.....	.....	6.40	5.65	.....	5.40	6.45
11	6.60	6.60	6.50	6.70	7.00	.....	.....	6.10	5.00	.....	5.50	6.60
12	7.00	6.70	6.50	6.50	6.80	.....	.....	5.70	5.15	.....	5.50	6.55
13	6.70	5.90	6.60	6.40	6.70	.....	.....	5.30	5.50	4.50	5.60	6.55
14	7.00	7.20	7.00	6.30	6.60	.....	.....	.....	5.05	4.50	5.60	6.55
15	6.90	6.70	7.10	6.15	6.50	.....	3.60	.....	.....	4.50	5.70	6.60
16	6.85	6.70	7.00	6.00	6.40	.....	3.60	.....	.....	4.50	5.70	6.60
17	6.70	6.95	6.90	6.05	6.50	.....	3.60	.....	.....	4.50	5.80	6.05
18	6.55	6.80	6.90	6.90	6.60	.....	3.60	.....	.....	4.50	5.80	6.40
19	6.55	6.80	6.80	7.35	6.70	.....	9.05	.....	7.25	4.50	5.90	6.50
20	6.55	6.80	6.50	7.80	7.45	.....	9.25	.....	6.05	4.50	6.00	6.45
21	6.60	6.80	6.40	7.95	7.40	.....	7.60	.....	5.50	4.50	6.00	6.55
22	6.50	6.80	6.40	7.95	7.30	.....	6.75	.....	5.15	4.50	6.10	6.55
23	6.60	6.80	6.40	7.80	7.30	.....	6.25	.....	5.00	4.50	6.20	6.60
24	6.70	6.70	6.40	7.70	7.20	.....	6.15	.....	5.00	4.60	6.20	6.65
25	6.70	6.80	6.40	7.70	7.00	.....	7.60	.....	.....	4.60	6.30	6.70
26	6.60	6.80	6.30	7.70	6.95	.....	7.50	.....	.....	4.70	6.30	6.65
27	6.60	6.80	6.30	7.70	6.80	.....	6.55	.....	.....	4.70	6.40	6.65
28	6.60	6.80	6.50	7.70	6.65	.....	6.30	.....	.....	4.80	6.40	6.65
29	6.60	.....	6.70	7.80	6.55	.....	6.20	.....	.....	4.80	6.50	6.75
30	6.60	.....	6.85	7.70	6.30	.....	6.25	.....	.....	4.90	6.50	6.85
31	6.65	.....	7.00	.....	6.20	.....	6.20	.....	.....	4.90	.....	6.80

June 8 to July 14, inclusive, no flow in river.
August 14 to September 8, inclusive, no flow in river.
September 15 to 18, inclusive, September 25 to October 22, inclusive, no flow in river.

RIO GRANDE AT EL PASO, TEXAS.

This is an important station, and measurements have been made here for a long period. During the last three years the work has been carried on under the direction of W. W. Follett, consulting engineer International (Water) Boundary Commission. This commission has had charge of the investigation looking toward the building of an international dam at El Paso. The present station is located at Courchesne's limekiln, 4 miles north of El Paso, Texas. The river heights are measured at the masonry pump foundation pier, 150 feet above the kiln. The top of the downstream chisel draft is assumed to be at a gage height of 15 feet, and the distance to the water surface below is measured with a carefully graduated rod. The left bank of the river is formed by the loose rock fill of the Atchison, Topeka and Santa Fe Railroad embankments, and will not overflow; the right

bank, however, is made ground and is liable to overflow at high stages. Owing to the shifting character of the bed of the stream, it has been necessary to make a large number of discharge measurements at this point in order to obtain an accurate idea of the discharge. Results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 259; 1897, Nineteenth Annual Report, Part IV, page 390; 1898, Twentieth Annual Report, Part IV, page 312. There were 32 discharge measurements made by T. M. Courchesne during 1899, as follows:

Measurements of Rio Grande at El Paso, Texas.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Second-ft.*	1899.	*Feet.*	*Second-ft.*
Jan. 4	6.40	290	Mar. 16	5.70	85
Jan. 9	6.10	226	Mar. 18	5.60	69
Jan. 12	6.00	173	Mar. 20	5.70	78
Jan. 14	5.90	126	Mar. 22	5.80	93
Jan. 16	5.90	126	Mar. 25	5.60	66
Jan. 18	6.40	244	Apr. 11	5.50	48
Jan. 21	6.30	249	Apr. 14	5.20	31
Jan. 23	6.10	181	May 8	6.90	336
Jan. 26	6.40	261	Dec. 14	5.40	94
Jan. 28	6.20	187	Dec. 16	5.30	70
Jan. 31	6.10	188	Dec. 18	5.10	48
Feb. 2	6.10	167	Dec. 20	5.10	47
Feb. 4	6.00	147	Dec. 23	5.20	56
Mar. 8	6.30	216	Dec. 26	5.30	72
Mar. 11	6.00	144	Dec. 28	5.50	101
Mar. 13	5.80	112	Dec. 30	5.40	104

Daily gage height, in feet, of Rio Grande at El Paso, Texas, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Dec.
1	6.15	6.10	6.25	6.05	7.45	(a)	(a)	5.70	(a)
2	6.20	6.10	6.15	5.50	7.60	(a)	(a)	5.00	(a)
3	6.40	6.00	6.20	5.05	7.50	(a)	(a)	5.00	(a)
4	6.40	6.00	6.15	5.05	7.40	(a)	(a)	4.90	(a)
5	6.25	5.90	6.20	5.05	7.30	(a)	(a)	4.85	4.30
6	6.15	6.25	6.20	5.00	7.10	(a)	(a)	4.65	4.40
7	6.10	6.50	6.25	4.95	6.85	(a)	(a)	4.45	4.50
8	6.10	6.30	6.30	5.10	6.85	(a)	(a)	4.15	4.50
9	6.10	6.40	6.20	5.25	6.55	(a)	(a)	.....	4.50
10	6.10	6.40	6.10	5.40	6.30	(a)	(a)	.....	4.50
11	6.00	6.40	6.00	5.50	6.00	(a)	(a)	.....	4.50
12	6.00	6.30	5.90	5.40	5.85	(a)	(a)	.....	4.75
13	5.90	5.90	5.80	5.25	5.65	(a)	(a)	.....	5.10
14	5.90	6.20	5.80	5.20	5.70	(a)	(a)	.....	5.40
15	5.90	6.00	5.75	5.10	5.55	(a)	(a)	.....	5.40
16	5.90	6.00	5.70	5.10	5.40	(a)	(a)	.....	5.30
17	6.20	6.00	5.65	5.10	5.50	(a)	(a)	.....	5.20
18	6.40	6.05	5.60	4.90	5.15	(a)	4.45	.....	5.10
19	6.40	6.20	5.60	4.90	4.95	(a)	5.85	.....	5.10
20	6.40	6.10	5.70	4.90	4.85	(a)	6.60	.....	5.10
21	6.30	6.20	5.80	4.95	4.80	(a)	7.90	.....	5.10
22	6.30	6.50	5.80	5.00	4.70	(a)	9.05	.....	5.15
23	6.10	6.55	5.65	5.35	4.60	(a)	9.05	.....	5.20
24	6.20	6.35	5.60	7.45	4.60	(a)	8.40	.....	5.20
25	6.25	6.30	5.60	7.60	4.60	(a)	8.20	.....	5.20
26	6.35	6.30	5.45	7.50	4.60	(a)	7.85	.....	5.30
27	6.30	6.25	5.45	7.30	4.60	(a)	7.55	.....	5.25
28	6.20	6.20	5.50	7.20	4.60	(a)	6.90	.....	5.40
29	6.20	.....	5.40	7.30	4.60	(a)	6.70	.....	5.50
30	6.10	.....	5.40	7.30	4.55	(a)	6.65	.....	5.40
31	6.10	.....	5.75	.....	4.50	(a)	6.35	.....	5.40

a Not flowing from June 1 to July 17 and from August 9 to November 30.

PECOS RIVER AT PECOS, TEXAS.

This stream rises on the eastern slope of the Santa Fe Range in northern New Mexico. Its course is first southerly, through a typical mountainous and canyon country, until it reaches Fort Sumner, when the character of the topography changes. The river then takes a more southerly course and the country then changes from a rolling to an almost flat area. A number of large irrigation enterprises have been completed within the last few years and now irrigate large areas in the vicinity of Roswell and Eddy, New Mexico, and even extend down into Texas. The summer flow of the river is largely dependent upon numerous springs, which occur in the limestone country in the vicinity of Roswell and below. Owing to the numerous diversions for irrigating purposes, however, the river would be dry in the summer where it crosses into Texas were it not for the waters which are gradually returning to the river through seepage. This water, unfortunately, is impregnated to a considerable extent with alkali, which renders it undesirable for irrigating purposes. The station on this river was established January 1, 1898, and is located at a point 6 miles above the town of Pecos, Texas, at the flume of the Margueretta canal. This canal diverts water from the river 3 miles above this point on the west side, and then the water is carried over to the east side by means of a flume, where it is used below. The bench mark of the gage is the top of north pier at west side of flume, and its elevation is 20.7 feet above gage datum. The channel at this point is nearly straight, the water sluggish, the banks high, and the bottom sandy and shifting. One measurement of the discharge in the flume was made on June 22, when it was found to be 85 second-feet. Two measurements were made on the main river by Prof. Thomas U. Taylor in 1899, as follows: June 22, at a gage height of 0.70 foot, the discharge was 21 second-feet; the second measurement, on December 28, at a gage height of 2.90 feet, gave a discharge of 345 second-feet.

In the vicinity of Fort Stockton, Pecos County, Texas, occur a series of springs which contribute to the discharge of Comanche Creek, a tributary of Pecos River. On June 23, 1899, their discharge was measured by Prof. Thomas U. Taylor at the ford one-half mile east of the court-house, and the discharge was found to be 66 second-feet.

Daily gage height, in feet, of Pecos River at Pecos, Texas, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.80	3.00	2.80	1.00	1.00	0.45	0.75	5.35	1.20	1.25	1.30	3.00
2	2.80	3.00	2.70	1.00	1.00	.45	.90	4.80	1.30	1.20	1.30	3.00
3	2.60	3.00	2.60	1.00	1.00	.40	.70	3.75	1.30	1.20	1.30	2.95
4	2.60	2.95	2.50	1.00	1.00	.40	.80	3.65	1.25	1.85	1.20	2.90
5	2.60	2.80	2.50	1.00	1.00	.40	.80	3.45	1.20	1.60	1.35	2.90
6	2.55	2.65	2.75	1.00	1.00	.40	.80	2.65	1.20	1.50	1.40	2.90
7	2.50	2.45	2.65	1.00	1.00	.40	.80	2.15	1.20	1.50	1.40	3.00
8	2.50	2.40	2.55	1.00	1.00	.40	1.50	2.05	1.20	1.45	1.40	3.05
9	2.50	2.70	2.35	1.00	1.55	.40	3.75	1.90	1.30	1.35	1.45	3.00
10	2.50	3.00	2.10	1.00	1.50	.40	2.20	1.75	1.50	1.30	1.45	3.10
11	3.10	3.00	1.80	.95	1.00	1.75	1.60	1.70	2.40	1.30	1.50	3.00
12	3.10	2.90	1.45	.90	1.00	1.00	1.35	1.80	1.85	1.20	1.40	2.90
13	3.10	2.85	1.35	.90	1.00	.60	1.15	2.20	3.00	1.20	1.40	3.00
14	3.00	3.00	1.30	.90	1.00	.60	1.00	2.15	2.40	1.20	1.40	3.00
15	3.00	3.00	1.20	1.10	.95	.60	.85	2.05	1.80	1.20	1.40	3.00
16	3.00	3.00	1.20	3.50	.90	1.60	1.15	2.00	1.65	1.35	1.40	3.00
17	3.00	2.90	1.10	2.75	.70	2.30	.80	2.00	1.35	1.10	1.30	3.00
18	3.00	2.80	1.10	1.95	.50	1.15	4.35	1.95	1.30	1.10	1.30	3.10
19	3.00	2.70	1.10	1.60	.50	.85	1.95	1.50	1.30	1.10	2.65	3.10
20	3.00	2.70	1.10	1.45	.50	.70	3.00	1.40	1.40	1.00	4.40	3.10
21	3.00	2.70	1.20	1.35	.50	.70	3.00	1.30	1.60	1.00	3.30	3.20
22	3.00	2.70	1.15	1.30	.50	.70	2.65	1.40	2.00	1.00	2.60	3.30
23	3.00	2.70	1.10	1.30	.50	.70	3.05	1.40	2.65	1.10	2.25	3.05
24	2.95	2.60	1.10	1.15	.50	.70	4.25	1.40	2.45	1.10	2.05	3.25
25	2.90	2.50	1.10	1.10	.50	.70	5.00	1.40	2.00	1.10	2.00	3.80
26	3.05	2.75	1.30	1.10	.50	.70	5.55	1.40	1.80	1.10	2.00	3.15
27	3.00	2.70	1.10	1.10	.50	.70	5.60	1.40	1.50	1.20	2.00	3.05
28	3.00	2.70	1.00	1.10	.50	.70	5.50	1.30	1.45	1.20	2.55	3.00
29	3.05	.....	1.00	1.00	.50	.70	5.50	1.30	1.40	1.20	2.50	2.90
30	3.00	.....	1.00	1.00	.50	.70	5.50	1.30	1.35	1.20	2.45	2.90
31	3.00	.....	1.00	.....	.50	.....	5.50	1.30	.....	1.30	.....	2.95

GREEN RIVER AT GREENRIVER, WYOMING.

This river has its source in the Wind River and Gros Ventre mountains in western Wyoming; it flows southerly, receiving a number of important tributaries from either side, and after crossing the State line flows through Utah. In this State its principal tributaries are Yampa and White rivers from the east and Duchesne River from the west. Sixty miles below the crossing of the Rio Grande Western Railway in Utah, Green River joins the Grand River to form the Colorado. Two gaging stations have been maintained on the main river, one at Greenriver, Wyoming, at the crossing of the Union Pacific Railroad, and the other at Blake, Utah, at the crossing of the Rio Grande Western Railway. The former station, established May 2, 1895, is located at the pump house of the Union Pacific Railroad Company. The rod is fastened to a pile near the east end of the bridge. The bench mark consists of a cross on the third step from the bottom on the south end of the east abutment, and is 12.48 feet above gage datum. The rod was last verified with the bench mark August 30, 1899. As the section under the railroad bridge is poor, discharge measurements are made from the iron highway bridge about one-half mile below. The average annual discharge of Green River at this point having been determined for the last five years, and as the water supply is far greater than the demand by irrigators, observations will be discontinued in the spring and attention given to the

more important tributaries of the river. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 275; 1897, Nineteenth Annual Report, Part IV, page 395; 1898, Twentieth Annual Report, Part IV, page 380. The following discharge measurements were made by A. J. Parshall during 1889:

April 19, gage height, 1.35 feet; discharge, 1,595 second-feet.
May 13, gage height, 2.20 feet; discharge, 2,661 second-feet.
May 25, gage height, 2.55 feet; discharge, 3,422 second-feet.
June 7, gage height, 3.80 feet; discharge, 8,234 second-feet.
June 20, gage height, 5.30 feet; discharge, 15,305 second-feet.
July 5, gage height, 6.25 feet; discharge, 18,372 second-feet.
August 30, gage height, 2.10 feet; discharge, 1,632 second-feet.

Daily gage height, in feet, of Green River at Greenriver, Wyoming, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	1.80	1.90	1.00	1.78	3.20	6.38	3.88	2.05	1.45	1.60	1.20
2	.....	.....	.....	.70	1.58	3.25	6.43	3.78	2.05	1.45	.....	.....
3	1.50	.....	.....	.95	1.50	3.35	6.50	3.70	1.95	1.45	1.60	1.20
4	.....	.....	.....	1.10	1.43	3.48	6.43	3.68	1.90	1.40	.....	.....
5	.....	.....	.....	.90	1.33	3.55	6.13	3.65	1.90	1.40	1.60	1.40
6	.....	.....	.....	.80	1.30	4.00	5.85	3.65	1.90	1.40	.....	.....
7	.....	.....	.....	.90	1.33	3.95	5.75	3.58	1.90	1.40	1.55	1.45
8	.....	1.80	1.70	.85	1.50	3.70	5.78	3.58	1.85	1.45	.....	.....
9	1.60	.....	.....	.95	1.50	3.45	5.65	3.50	1.85	1.45	1.55	1.45
10	.....	.....	.....	.90	1.68	3.38	5.60	3.45	1.80	1.45	.....	.....
11	.....	.....	.....	1.30	1.95	3.43	5.53	3.40	1.78	1.48	1.50	1.45
12	.....	.....	.....	1.35	2.15	3.78	5.45	3.40	1.73	1.50	.....	.....
13	1.60	.....	.....	1.50	2.28	4.13	5.45	3.35	1.78	1.55	1.50	1.45
14	.....	.....	.....	1.50	2.55	4.68	5.48	3.23	1.85	1.58	.....	.....
15	.....	1.90	1.30	1.60	2.58	4.78	5.53	3.13	1.80	1.60	1.50	1.45
16	.....	.....	.....	1.50	2.80	4.35	5.45	3.00	1.75	1.60	.....	.....
17	.....	.....	.....	1.40	2.78	4.30	5.38	2.95	1.75	1.60	1.50	1.40
18	.....	.....	.....	1.40	2.65	4.50	5.23	2.98	1.75	1.60	.....	.....
19	1.60	.....	.....	1.35	2.63	4.98	4.95	2.88	1.73	1.63	1.45	1.40
20	.....	.....	.....	1.35	2.50	5.40	4.78	2.68	1.70	1.65	.....	.....
21	.....	.....	.....	1.30	2.80	5.80	4.63	2.60	1.65	1.68	1.40	1.45
22	.....	1.90	1.30	1.25	2.78	6.18	4.50	2.55	1.65	1.70	.....	.....
23	.....	.....	.....	1.35	2.73	6.50	4.45	2.58	1.60	1.70	1.30	1.45
24	.....	.....	.....	1.45	2.58	6.63	4.40	2.50	1.60	1.70	.....	.....
25	1.70	.....	.....	1.65	2.55	6.30	4.33	2.45	1.60	1.65	1.25	1.50
26	.....	.....	.....	2.00	2.78	6.05	4.18	2.40	1.55	1.65	.....	.....
27	1.70	.....	.....	1.95	3.08	5.98	4.03	2.38	1.55	1.63	1.25	1.55
28	.....	1.90	.....	1.90	3.18	6.03	3.98	2.30	1.50	1.60	.....	.....
29	.....	.....	1.70	1.90	3.20	6.10	3.95	2.23	1.50	1.60	1.25	1.55
30	1.55	.....	.....	1.83	3.25	6.28	3.95	2.10	1.45	1.60	.....	1.60
31	.....	.....	.....	.....	3.20	.....	3.95	2.05	.....	1.60	.....	.....

BLACK FORK AT GRANGER, WYOMING.

This tributary of Green River rises in the extreme southwestern corner of Wyoming, and flows in a general northwesterly direction until after its junction with Hams Fork, when it turns southeasterly and joins Green River 20 miles below Greenriver station, Wyoming. Considerable irrigation is practiced on its head-water streams, almost wholly for forage crops, as the elevation is too high for diversified farming. The general industry of the country is stock raising, the herds being ranged on the hillside during the summer, and during the winter fed the hay raised by irrigation. The station on this river was established April 28, 1897, and is located below the mouth of Hams Fork and about a quarter of a mile below Granger. The rod consists of a horizontal timber fastened to two upright posts set firmly in the bank of the river. One end of the timber to which the wire gage is

fastened projects out over the water. The bench mark is a rail spike in an old tie 25 feet west of inside post of gage, marked "B. M." in black paint, and is at an elevation of 8.74 feet above gage datum. The rod was last verified with the bench mark August 30, 1899. The results of measurements may be found as follows: 1897, Nineteenth Annual Report, Part IV, page 393; 1898, Twentieth Annual Report, Part IV, page 382. The following discharge measurements were made by A. J. Parshall during 1899:

April 19, gage height, 1.85 feet; discharge, 769 second-feet.
May 13, gage height, 3.30 feet; discharge, 2,229 second-feet.
May 25, gage height, 3.60 feet; discharge, 2,535 second-feet.
June 7, gage height, 5.10 feet; discharge, 4,776 second-feet.
June 20, gage height, 5.70 feet; discharge, 5,567 second-feet.
July 5, gage height, 3.90 feet; discharge, 2,674 second-feet.
August 30, gage height, 0.20 foot; discharge, 101 second-feet.

Daily gage height, in feet, of Black Fork at Granger, Wyoming, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	.....	2.20	.....	1.80	3.90	4.40	1.50	0.80	0.30	.....	.....
2	1.80	.....	.....	2.90	2.20	3.90	4.50	1.40	.80	.30	.....	1.30
3	.....	.....	.....	2.90	2.65	3.90	4.60	1.40	.80	.30	.....	.....
4	.....	2.10	.....	2.90	1.60	4.20	4.30	1.40	.70	.30	0.80	.....
5	.....	.....	.....	2.95	1.70	4.30	3.90	1.40	.65	.35	.....	.....
6	.....	.....	.....	3.20	1.60	4.50	3.80	1.40	.60	.40	.....	.....
7	.....	.....	.....	3.25	1.70	5.05	3.60	1.40	.60	.50	.....	.....
8	.....	.....	2.30	1.80	1.90	5.40	3.50	1.60	.60	.50	.....	.....
9	1.60	.....	.....	1.80	2.00	5.20	3.30	1.50	.60	.50	.....	1.00
10	.....	.....	.....	1.60	2.20	4.90	3.10	1.50	.60	.50	.....	.....
11	.....	2.10	.....	1.40	2.65	4.85	3.10	1.50	.50	.50	.80	.....
12	.....	.....	.....	1.60	2.75	5.10	3.00	1.50	.50	.60	.....	.....
13	.....	.....	.....	1.65	3.35	5.50	3.20	1.25	.50	.60	.....	.....
14	.....	.....	.....	1.60	3.80	6.05	3.20	1.20	.50	.70	.....	.....
15	.....	.....	2.50	1.70	4.20	6.05	3.20	1.20	.50	.70	.....	.....
16	1.70	.....	.....	1.80	4.50	5.60	3.10	1.20	.50	.70	.....	1.00
17	.....	.....	.....	1.75	4.50	5.50	3.20	1.10	.40	.70	.....	.....
18	.....	2.20	.....	1.60	4.10	5.40	2.90	1.10	.40	.70	.90	.....
19	.....	.....	.....	1.85	3.80	5.50	2.55	1.00	.45	.70	.....	.....
20	.....	.....	.....	2.10	3.90	5.70	2.30	1.00	.50	.80	.....	.....
21	.....	.....	.....	1.50	4.00	5.90	2.20	.95	.50	.70	.....	.....
22	1.90	.....	2.70	1.50	3.80	6.25	2.05	.90	.50	.70	.....	.....
23	.....	.....	.....	1.60	3.80	6.00	2.00	.90	.50	.80	.....	1.50
24	.....	.....	.....	1.85	3.30	5.50	1.90	.80	.50	.80	.....	.....
25	.....	2.30	.....	1.80	3.60	5.30	1.90	.70	.40	.80	.90	.....
26	.....	.....	.....	2.00	4.10	5.00	1.80	.70	.40	.80	.....	.....
27	.....	.....	.....	2.20	4.20	4.70	1.80	.70	.30	.80	.....	.....
28	1.90	.....	.....	2.00	4.30	4.60	1.80	.70	.30	.70	.....	.....
29	.....	.....	3.80	1.80	4.30	4.40	1.80	.70	.30	.70	.....	.....
30	.....	.....	.....	1.80	3.90	4.30	1.70	.70	.30	.75	.....	1.30
31	.....	.....	.....	.....	3.90	.....	1.50	.70	.....	.80	.....	.....

UINTA RIVER NEAR WHITEROCKS, UTAH.

Uinta River has its source on the southern slope of the Uinta Mountains in northeastern Utah, and flows in a general southeasterly direction, emptying into Duchesne River about 15 miles above its mouth. Its drainage area is included within the Uinta Indian Reservation. During the fall of 1899 an investigation of the water supply of the Uinta Indian Reservation was begun by Cyrus C. Babb, and in this connection a number of gaging stations were established. Uinta River emerges from its canyon about 10 miles northwest of the Indian agency at Whiterocks, and at this point a gaging station was estab-

lished September 16, 1899. The gage rod is a 2 by 4 inch timber, 12 feet long, bolted to two trees on the left bank of the stream. The bench mark is a nail in an aspen tree 125 feet north of the rod, and its elevation is 8.93 feet above gage datum. Discharge measurements are made by car and cable. The bed of the stream is very rocky and strewn with large bowlders, and the station is not altogether satisfactory, on account of the roughness of the channel. During high water the velocity undoubtedly will be great, owing to the rapid fall of the water. A few hundred yards above the station an important tributary comes in from the east. At the present location a second channel has to be measured, but it will never carry a large volume of water. Farther down the stream a number of larger channels are formed, so that it is difficult to obtain a satisfactory station. Daily records of gage heights were not maintained at this point, but frequent measurements of discharge were made by Cyrus C. Babb and C. T. Prall during 1899, as follows:

Measurements of Uinta River near Whiterocks, Utah.

1899.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
September 16	1.15	191	November 25	1.00	119
September 28	1.00	142	December 4	1.00	136
October 6	1.00	159	December 11	.97	136
October 18	1.10	165	December 18	1.00	124
November 2	1.00	141	December 28	(a)	86

a Ice.

WHITEROCKS RIVER NEAR WHITEROCKS, UTAH.

This stream drains the country immediately east of the head waters of Uinta River. It has its source in the peaks of the Uinta Mountains, which attain elevations of over 13,000 feet. The general course of the river is southerly, and it joins the main Uinta through numerous channels between Whiterocks and Fort Duchesne. A gaging station was established in the canyon of this river about 10 miles above the United States Indian agency at Whiterocks on September 15, 1899, by Cyrus C. Babb, in connection with the investigation of a water supp y for the Uinta Indian Reservation. The gage rod consists of a 2 by 4 inch by 12 foot timber bolted to the triple trunk of a tree on the left bank of the stream. The bench mark is a nail in a burnt tree 50 feet east of the rod, and is at an elevation of 10.12 feet above gage datum. Discharge measurements are made from a car and cable 200 feet above the gage rod. The bed of this river is very rocky, is strewn with large bowlders, and although permanent in character is not altogether satisfactory because of the fact that it is impossible to obtain accurate soundings. Daily gage heights were not read at this point, owing to its distance

from any reliable observer. The following discharge measurements were made by C. C. Babb and C. T. Prall during 1899:

Measurements of Whiterocks River near Whiterocks, Utah.

1899.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
September 15	.....	93	November 27	1.05	66
September 29	1.00	58	December 5	1.10	71
October 7	1.00	75	December 12	.95	59
October 17	1.10	85	December 19	.95	56
November 1	1.00	65	December 29	(a)	66

a Ice.

UINTA RIVER AT FORT DUCHESNE, UTAH.

This river, on its emergence from its canyon, spreads out in numerous channels over its flood plain until a short distance above Fort Duchesne, where its waters are collected in one channel. Whiterocks River enters some distance above this point. A number of canals for the use of the Indians divert water between Fort Duchesne and the agency. On the east side are a number of small ditches, which in the aggregate take considerable water; but the amount is difficult to estimate. On the east side are two principal ditches, known as Canal No. 1 and Bench ditch. The former was measured on October 14, 1899, and was then carrying 16 second-feet; its maximum capacity is about double this quantity. Bench ditch, near its head, on the same day, was discharging 49 second-feet; its maximum capacity is somewhere in the neighborhood of 75 second-feet. This station was established September 14, 1899, in connection with the investigation of the water supply for the Uinta Indian Reservation, and is located at the highway bridge at the fort. The permanent rod was established November 8, 1899, and is nailed to the southern end of the east crib of the new bridge. The bench mark is a nail in the southeast crib in the first header above the bottom, and is at an elevation of 4,910.13 feet. The elevation of the zero of the rod is 4,907.20 feet. Daily gage readings were not obtained at this place. The following measurements of discharge were made by Cyrus C. Babb and C. T. Prall during 1899:

Measurements of Uinta River at Fort Duchesne, Utah.

1899.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
September 14	.....	86	December 1	2.55	120
September 26	2.30	71	December 8	2.43	112
October 27	2.40	83	December 13	2.40	107
November 3	2.50	102	December 21	2.35	102
November 18	2.57	120	December 27	2.59	131

UINTA RIVER AT OURAY SCHOOL.

This river, after leaving Fort Duchesne, receives as its principal tributary Dry Gulch Creek, which enters from the west. The natural flow of this tributary occurs only during flood stages, but for several years there has been a constant stream in it, being the waste water from the Indians' ditches above, principally from Canal No. 1 and Bench ditch. The station was established November 8, 1899, and is located at the highway bridge over the river near the Ouray School. The rod is nailed to the east end of the south crib of the wagon bridge. Bench mark No. 1 is the head of a nail in the extreme northeast corner of the bridge floor, and is at an elevation of 4,745.97 feet above sea; bench mark No. 2 is a nail in the flagstaff of the school, with an elevation of 4,760 feet. The elevation of the zero of the rod is 4,737.36 feet. During low water measurements are made, by wading, at a section 200 feet below the bridge, and at high stages they are made from the bridge itself. The section is a good one, although the center pier of the bridge will interfere somewhat with the accuracy of the results when measurements are taken there. The following measurements of discharge were made by Cyrus C. Babb and C. T. Prall during 1899:

November 15, gage height, 0.53 foot; discharge, 124 second-feet.
November 20, gage height, 0.56 foot; discharge, 124 second-feet.
December 2, gage height, 0.49 foot; discharge, 120 second-feet.
December 9, gage height, 0.50 foot; discharge, 115 second-feet.
December 16, gage height, 0.45 foot; discharge, 103 second-feet.

Daily gage height, in feet, of Uinta River at Ouray School, Utah, for 1899.

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1	.....	0.51	9	.....	.52	17	0.68	.....	25	0.46	.....
2	.....	.50	10	.....	.....	18	.64	.....	26	.51	.....
3	.....	.30	11	.....	.....	19	.60	.....	27	.46	.....
4	.....	.18	12	0.57	.....	20	.58	.....	28	.61	.....
5	.....	.40	13	.55	.....	21	.55	.....	29	.58	.....
6	.....	.40	14	.58	.....	22	.50	.....	30	.50	.....
7	.....	.....	15	.57	.....	23	.59	.....	31	.....	.....
8	.....	.60	16	.99	.....	24	.52	.....			

DUCHESNE RIVER AT PRICE ROAD BRIDGE, UTAH.

This stream has its source in the high peaks of the Uinta and Wasatch mountains, and flows in a general easterly direction, emptying into Green River 3 miles above the mouth of White River. Practically the entire drainage basin is included within the Uinta Indian Reservation. Strawberry Creek is an important tributary of the Duchesne and includes within its basin a tract of very fine grazing land, known as Strawberry Valley. The area is of a rolling character in contrast to the basin of the upper Duchesne, which is distinctly mountainous. A number of measurements were made of the tributaries of Duchesne

River in the fall of 1899, in connection with the water-supply investigations for the Uinta Indian Reservation. In Strawberry Valley a number of small tributaries, averaging about one second-foot each, contribute to the supply of the river. In September, 1899, Currant Creek was discharging 20 second-feet at the crossing of the Provo and Fort Duchesne road. Red Creek, farther to the east, was at the same date carrying 8 second-feet. Strawberry Creek 4 miles above its mouth was measured on September 10 and found to be carrying 13¼ second-feet. Duchesne River immediately above Strawberry Creek was carrying on the same day 302 second-feet. Lake Creek is an important tributary of Duchesne River from the north. At the bridge near its mouth it was found to be carrying 128 second-feet on September 11. The station on Duchesne River was established October 26, 1899, and is located 3 miles below the mouth of Lake Creek at the highway bridge on the stage road from Price to Fort Duchesne. The permanent gage rod was placed November 16, 1899, and is nailed to the east side of the center pier. Bench mark No. 1 is a wire nail in a log close to the rod, and is opposite the 7-foot mark. Bench mark No. 2 is a wire nail on the west side of the crib, with an elevation of 5.48 feet above gage datum. The section at this point is very good, with a moderate velocity of water. There is one pier in the center of the stream which does not materially affect the accuracy of the results at low water, but presumably will to a certain extent during the flood season. The following measurements of discharge were made by Cyrus C. Babb and C. T. Prall during 1899:

October 26, gage height, 5.48 feet; discharge, 403 second-feet.
November 16, gage height, 5.50 feet; discharge, 436 second-feet.
November 29, gage height, 5.38 feet; discharge, 360 second-feet.
December 7, gage height, 5.50 feet; discharge, 386 second feet.
December 14, gage height, 5.10 feet; discharge, 309 second-feet.

Daily gage height, in feet, of Duchesne River at Price road bridge, Utah, for 1899.

Day.	Dec.	Day.	Dec.	Day.	Dec.	Day.	Dec.	Day.	Dec.
1	.....	8	5.52	14	5.00	20	5.40	26	5.94
2	.....	9	5.52	15	5.05	21	5.35	27	5.98
3	5.32	10	5.04	16	5.06	22	5.45	28	6.00
4	5.32	11	5.04	17	5.15	23	5.65	29	6.00
5	5.36	12	5.00	18	5.40	24	5.75	30	6.00
6	5.20	13	5.00	19	5.40	25	5.92	31	.....
7	5.52								

GREEN RIVER AT BLAKE, UTAH.

This river, in the lower portion of its course, drains a rough and broken country in eastern Utah not susceptible of irrigation and hardly adapted to grazing purposes. It is in canyon most of its way below the Rio Grande Western Railway and is very inaccessible. About 6

miles below the railroad crossing it receives the waters of Grand River, and the two streams form Colorado River. The station located at Blake, Utah, was established October 21, 1894. The rod of the wire gage is nailed to the guard rail on the lower side of the railroad bridge. The elevation of the top of the pier, to which the old vertical rod is attached, is 22 feet above gage datum. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 278; 1897, Nineteenth Annual Report, Part IV, page 398; 1898, Twentieth Annual Report, Part IV, page 387. One measurement of discharge was made during 1899 by J. S. Baker, on June 28, when, at a gage height of 10.19 feet, a discharge of 52,378 second-feet was found.

Daily gage height, in feet, of Green River at Blake, Utah, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	1.80	2.10	2.00	3.55	5.85	7.15	9.55	5.40	3.25	2.50
2	1.80	2.10	2.00	3.50	5.65	7.25	9.35	5.15	3.20	2.40
3	1.80	2.20	2.10	3.50	5.55	7.35	9.15	5.20	3.20	2.40
4	1.80	2.20	2.10	3.50	5.25	7.45	8.95	6.60	3.20	2.40
5	1.80	2.10	2.20	3.40	5.05	7.55	8.75	6.55	3.20	2.40
6	1.80	2.10	2.20	3.40	4.85	7.65	8.55	6.40	3.10	2.40
7	1.80	2.10	2.20	3.40	4.95	7.75	8.40	6.30	3.10	2.40
8	1.80	2.10	2.20	3.30	5.15	7.85	8.30	6.15	3.10	2.40
9	1.80	2.10	2.20	3.30	5.50	8.05	8.20	6.00	3.10	2.40
10	1.80	2.10	2.30	3.20	5.90	8.20	8.10	5.85	3.00	2.40
11	1.80	2.10	2.30	3.20	6.15	8.30	8.00	5.65	3.00	2.40
12	1.80	2.10	2.30	3.30	6.35	8.40	7.90	5.45	3.00	2.40
13	1.90	2.10	2.30	3.30	6.55	8.50	7.80	5.25	2.90	2.40
14	1.90	2.00	2.30	3.30	6.65	8.50	7.70	5.20	2.85	2.40
15	1.90	2.00	2.35	3.40	6.95	8.65	7.60	5.10	2.80	.....
16	1.90	2.00	2.40	3.50	7.30	8.90	7.50	5.00	2.80	.....
17	1.90	2.00	2.40	3.60	7.55	9.20	7.40	4.95	2.80	.....
18	1.90	2.10	2.40	3.75	7.75	9.15	7.30	4.85	2.70	.....
19	2.00	2.10	2.50	3.95	7.75	9.10	7.15	4.75	2.70	.....
20	2.00	2.10	2.60	4.15	7.65	9.40	7.00	4.65	2.65	.....
21	2.00	2.00	2.70	4.35	7.60	9.50	6.85	4.55	2.60	.....
22	2.00	2.00	2.85	4.55	7.60	9.75	6.65	4.45	2.60	.....
23	2.00	2.00	3.05	4.75	7.50	9.90	6.45	4.25	2.55	.....
24	2.00	2.00	3.25	4.95	7.50	10.00	6.25	4.05	2.50	.....
25	2.10	2.00	3.45	5.05	7.40	10.05	6.05	3.85	2.50	.....
26	2.10	2.00	3.65	5.25	7.25	10.25	5.90	3.65	2.50	.....
27	2.20	2.00	3.85	5.45	7.05	10.30	5.75	3.50	2.50	.....
28	2.20	2.00	4.05	5.65	6.90	10.15	5.60	3.50	2.50	.....
29	2.20	.....	4.25	5.85	6.95	9.95	5.50	3.45	2.50	.....
30	2.20	.....	4.10	6.00	7.05	9.75	5.50	3.40	2.50	.....
31	2.20	.....	3.75	.....	7.10	.....	5.45	3.30	.....	.....

Station discontinued November 15.

GRAND RIVER AT GLENWOOD SPRINGS, COLORADO.

This river has its source on the western slope of the Continental Divide in north-central Colorado, near the head waters of North Platte, South Platte, and Arkansas rivers. It flows in a general southwesterly direction, passing out of the State into Utah, where it joins the Green River to form the Colorado. Little irrigation is practiced along the main stream, owing to the comparatively small area of land that can be utilized for that purpose. Two stations were maintained on this river during 1899, one at Glenwood Springs and the other at Grand Junction, Colorado. The former station was established by A. L. Fellows May 12, 1899, at the request of the Denver and Rio Grande

Railroad Company, and is located at the railroad bridge one-fourth of a mile west of the railroad station, and above the mouth of Roaring Fork. A wire gage is here used. Discharge measurements are made at the wagon bridge opposite Colorado Hotel in the town. The channel is good, composed of gravel and rock, and not liable to great changes. The banks are not subject to overflow. Gage readings were taken only during the high-water season, having been discontinued July 17, but the station will probably be resumed in 1900, when continuous measurements will be made. Roaring Fork was measured twice during the year, the first time on June 17, when, during the flood stage, the discharge was found to be 11,258 second-feet; the second time on November 17, when a discharge of 457 second-feet was found. Three measurements at the gaging station were made by A. L. Fellows in 1899. The first, on May 12, at a gage height of 6.05 feet, showed a discharge of 17,577 second-feet; the second, on June 17, at a gage height of 10.22 feet, showed a discharge of 29,187 second-feet; the third, on November 17, at a gage height of 2.75 feet, gave a discharge of 1,084 second-feet.

Daily gage height, in feet, of Grand River at Glenwood Springs, Colorado, for 1899.

Day.	May.	June.	July.	Day.	May.	June.	July.	Day.	May.	June.	July.
1	.....	7.50	6.90	12	6.05	9.35	5.90	23	6.20	9.70	.....
2	.....	7.40	7.10	13	6.80	10.05	5.60	24	6.30	9.30	.....
3	.....	7.35	7.00	14	7.50	10.40	5.30	25	6.65	8.80	.....
4	.....	7.20	7.00	15	7.85	10.30	5.00	26	7.15	8.50	.....
5	.....	6.65	6.80	16	8.15	10.10	4.90	27	7.65	8.40	.....
6	.....	6.45	6.70	17	7.75	10.10	4.70	28	7.70	8.20	.....
7	.....	6.40	6.50	18	7.65	10.20	.....	29	7.45	7.20	.....
8	.....	6.60	6.40	19	7.80	10.60	.....	30	7.50	7.00	.....
9	.....	7.60	6.40	20	8.00	10.65	.....	31	7.60	.....	.....
10	.....	7.85	6.20	21	7.50	10.60	.....				
11	.....	8.25	6.10	22	6.75	10.40	.....				

Station discontinued July 18.

GRAND RIVER AT GRAND JUNCTION, COLORADO.

The station at this point, established October 18, 1894, is located at the wagon bridge across Grand River, near the pump house of the city waterworks at Grand Junction and a short distance above the mouth of Gunnison River. The river at this point discharges through two channels, and a separate record of each is maintained, with separate discharge measurements. The water in the right-hand channel does not run during the entire year, and in 1899 there was a discharge in it extending only from May 10 to July 15, inclusive. Gage rod No. 1, in the right-hand channel, consists of a 4 by 6 inch timber bolted to the bridge abutment on the right-hand side of the right channel. The bench mark is the top of the bridge abutment and is 12 feet above gage datum. The horizontal wire gage No. 2 is fastened to the upper side

of the bridge over the left channel. The bench mark is a cross on iron post of bridge at 592-foot mark on right abutment, and is 31 feet above gage datum. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 261; 1897, Nineteenth Annual Report, Part IV, page 401; 1898, Twentieth Annual Report, Part IV, page 389. Only two measurements of discharge were made during the year on the right channel, and these by A. L. Fellows. The first, on May 13, with a gage height of 3.15 feet, gave a discharge of 2,758 second-feet; the second, on June 18, with a gage height of 5.55 feet, showed a discharge of 8,954 second-feet. During 1899 the following measurements of discharge on the left channel were made by A. L. Fellows:

April 15, gage height, 4.70 feet; discharge, 2,946 second-feet.
May 13, gage height, 10 feet; discharge, 20,395 second-feet.
June 18, gage height, 11.55 feet; discharge, 30,000 second-feet.
September 19, gage height, 4.20 feet; discharge, 1,989 second-feet.
November 18, gage height, 3.90 feet; discharge, 1,916 second-feet.

Daily gage height, in feet, of Grand River at Grand Junction, Colorado, for 1899.

[Rod No. 1.]

Day.	May.	June.	July.	Day.	May.	June.	July.	Day.	May.	June.	July.
1	.....	3.90	3.90	12	1.95	4.85	0.90	23	2.70	5.80	.....
2	.....	3.95	4.00	13	3.05	5.45	.95	24	2.60	5.20	.....
3	.....	3.80	4.10	14	3.55	5.80	.80	25	2.95	4.85	.....
4	.....	3.40	3.90	15	4.00	5.90	.20	26	3.35	4.70	.....
5	.....	3.05	3.40	16	4.30	5.85	.....	27	3.35	4.50	.....
6	.....	2.95	2.90	17	4.45	5.75	.....	28	4.10	4.10	.....
7	.....	2.95	2.65	18	4.10	5.70	.....	29	3.85	4.00	.....
8	.....	3.25	2.25	19	4.20	5.90	.....	30	3.80	3.95	.....
9	.....	3.45	1.90	20	4.20	6.10	.....	31	3.95	.....	.....
10	0.40	3.90	1.50	21	4.15	6.45	.....				
11	.90	4.35	1.20	22	3.50	6.10	.....				

Water was running in this channel only during the time when records are given.

Daily gage height, in feet, of Grand River at Grand Junction, Colorado, for 1899.

[Rod No. 2.]

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	3.80	3.40	6.75	10.50	10.30	6.50	4.45	.....	.....	.....
2	.....	3.80	3.45	6.45	10.55	10.50	6.50	4.65	.....	.....	.....
3	.....	3.80	3.55	6.30	10.45	10.50	6.40	4.60	3.80	.....	.....
4	.....	3.40	3.60	6.05	10.00	10.35	7.35	4.45	.....	.....	.....
5	.....	.....	3.60	5.80	9.50	9.90	7.00	4.35	.....	.....	.....
6	.....	.....	3.60	5.75	9.35	9.70	6.85	4.30	.....	.....	.....
7	.....	.....	3.60	6.00	9.30	9.55	6.65	4.20	.....	.....	.....
8	.....	3.60	3.60	6.40	9.55	9.30	6.45	4.20	.....	.....	.....
9	.....	.....	3.60	6.95	9.85	9.05	6.20	4.15	.....	.....	.....
10	.....	.....	3.70	7.50	10.30	8.85	5.90	4.10	3.90	3.90	.....
11	.....	3.60	3.75	8.15	10.45	8.70	5.75	4.10	.....	.....	.....
12	.....	.....	3.85	8.95	10.70	8.55	5.65	4.10	.....	.....	3.70 *a*
13	.....	.....	4.05	9.75	11.20	8.65	5.55	4.05	.....	.....	.....
14	.....	.....	4.40	10.25	11.60	8.55	5.45	3.95	.....	.....	.....
15	.....	3.40	4.60	10.65	11.70	8.40	5.40	4.10	.....	3.90	.....
16	.....	.....	4.65	10.85	11.65	8.35	5.35	4.35	.....	.....	.....
17	.....	.....	4.90	10.80	11.65	8.15	5.25	4.30	.....	.....	.....
18	.....	3.50	5.20	10.70	11.60	7.85	5.20	4.30	.....	.....	.....
19	.....	.....	5.45	10.80	11.80	7.65	5.15	4.20	4.40	.....	.....
20	.....	.....	5.55	10.80	11.90	7.45	4.95	4.15	.....	.....	.....
21	.....	.....	5.35	10.60	11.95	7.35	4.85	4.10	.....	.....	.....
22	4.10	3.80	5.15	10.05	11.80	7.25	4.75	4.05	.....	3.90	.....
23	4.10	.....	5.35	9.50	11.55	7.15	4.65	3.95	.....	.....	.....
24	4.10	.....	5.95	9.55	11.15	7.05	4.55	3.90	.....	.....	.....
25	4.00	4.10	6.55	9.95	10.90	6.95	4.50	3.90	.....	.....	.....
26	.....	.....	7.00	10.45	10.80	6.85	4.45	3.90	.....	.....	.....
27	.....	.....	7.55	10.75	10.65	6.65	4.40	3.95	4.00	.....	.....
28	.....	.....	7.70	10.70	10.45	6.60	4.30	3.90	.....	.....	.....
29	.....	3.70	7.25	10.45	10.40	6.55	4.30	3.90	.....	3.90	.....
30	.....	.....	7.10	10.40	10.35	6.50	4.30	3.90	.....	.....	.....
31	.....	.....	.....	10.60	.....	6.50	4.30	.....	.....	.....	.....

a River frozen.

UNCOMPAHGRE RIVER AT FORT CRAWFORD, COLORADO.

This river has its source in Ouray County, in the high peaks in southwestern Colorado, and flows in a general northwesterly direction, entering Gunnison River at Delta. The upper portion of its drainage basin is mountainous, but proceeding downstream the character changes to a more rolling country, and irrigation is possible along the valleys and adjacent mesas. In the vicinity of Montrose a number of canals divert nearly all of the low water flow, and recourse must be had to storage for the further irrigation of the country. The station established June 25, 1895, is located about one-half mile east of the depot at Fort Crawford, at a wagon bridge, and is about 8 miles above Montrose. The gage consists of an inclined timber bolted to the bridge trestle on the right-hand side of the stream. The bench mark is a spike driven into the base of a cottonwood post near by, and is 9.18 feet above gage datum. The channel has been changing a great deal, and a new location for the station will probably be found during the next season. On September 20 a measurement of this river was made at Montrose, at a gage height of 0.40 foot, which gave a discharge of 15 second-feet. On November 20, at a gage height of 0.45 foot, at the same point, the discharge was 15 second-feet. A measurement of Montrose canal at its head gate was made September 21, at a gage height of 0.67 foot, and showed a discharge of 30

second-feet. Results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 266; 1897, Nineteenth Annual Report, Part IV, page 402; 1898, Twentieth Annual Report, Part IV, page 391. The following measurements of discharge were made by A. L. Fellows during 1899:

April 16, gage height, 4.50 feet; discharge, 328 second-feet.
May 15, gage height, 5.22 feet; discharge, 747 second-feet.
June 19, gage height, 5.18 feet; discharge, 773 second-feet.
September 21, gage height, 3.65 feet; discharge, 69 second-feet.
November 20, gage height, 3.70 feet; discharge, 79 second-feet.

Daily gage height, in feet, of Uncompahgre River at Fort Crawford, Colorado, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Day.	Apr.	May.	June.	July.	Aug.	Sept.
1	.....	4.35	5.05	4.70	4.00	3.00	17	4.55	5.35	5.35	4.35	3.85	3.70
2	3.80	4.45	5.05	4.70	4.15	3.00	18	4.60	5.45	5.35	4.45	3.85	3.60
3	3.85	4.35	4.80	4.55	4.80	2.95	19	4.55	5.30	5.30	4.45	3.80	3.70
4	3.80	4.35	4.40	4.25	4.65	2.95	20	4.45	4.95	5.25	4.35	3.80	3.75
5	3.88	4.30	4.35	4.35	4.55	2.80	21	4.35	4.90	5.10	4.35	3.75	3.75
6	3.82	4.40	5.05	4.25	4.30	2.80	22	4.40	4.80	5.05	4.25	3.70	3.60
7	3.80	4.35	5.05	4.20	3.90	2.80	23	4.60	4.80	4.95	4.05	3.70	3.50
8	3.85	4.30	5.00	4.10	3.95	2.80	24	4.58	4.65	4.80	4.10	3.35	3.50
9	3.95	4.35	5.15	4.25	3.80	2.80	25	4.75	4.95	4.80	4.10	3.85	3.55
10	4.25	4.40	5.45	4.20	3.90	2.75	26	4.70	5.00	5.00	4.20	3.85	3.55
11	4.15	4.70	5.40	4.35	4.00	2.80	27	4.68	5.10	4.90	4.35	3.60	3.50
12	4.25	4.65	5.45	4.45	4.00	2.85	28	4.55	5.10	4.85	4.00	3.45	3.50
13	4.30	4.90	5.85	4.50	3.95	2.90	29	4.45	5.10	4.85	4.10	3.40	3.45
14	4.35	5.10	5.75	4.50	3.95	3.85	30	4.30	5.35	4.70	4.15	3.30	3.45
15	4.40	5.15	5.85	4.35	3.95	3.95	31	.....	5.35	.....	4.05	3.20	.....
16	4.55	5.25	5.55	4.40	3.85	3.70							

Closed for the winter September 30.

GUNNISON RIVER AT GRAND JUNCTION, COLORADO.

This river, the principal tributary of Grand River, has its source on the western slope of the Continental Divide in south-central Colorado, and flows in a general westerly direction into Grand River at Grand Junction. There were two gaging stations maintained within its basin during the last season, one at Fort Crawford, on the Uncompahgre, and the other at Grand Junction, at the mouth of Gunnison River. This latter station was established in May, 1897, and is located at the iron highway bridge one and one-half miles from the town of Grand Junction. The gage is vertical and consists of a timber bolted to the stone pier of the bridge. The bench mark is the top of the capstone of the bridge pier, and is 17.60 feet above gage datum. The measurements here are not satisfactory, owing to the fact that at high stages of Grand River the water backs up the mouth of the Gunnison considerably above the point where the gage rod upon the latter is located, thus affecting the gage readings so seriously that no satisfactory rating table can be made for this point. The station will not be resumed the coming year. Results of measurements may be found as follows: 1897, Nineteenth Annual Report, Part IV, page

405; 1898, Twentieth Annual Report, Part IV, page 390. The following measurements of discharge were made by A. L. Fellows during 1899:

April 15, gage height, 3.50 feet; discharge, 3,002 second-feet.
May 13, gage height, 7 feet; discharge, 14,280 second-feet.
June 18, gage height, 7.15 feet; discharge, 12,769 second-feet.
September 19, gage height, 2.20 feet; discharge, 1,061 second-feet.
November 18, gage height, 2 feet; discharge, 968 second-feet.

Daily gage height, in feet, of Gunnison River at Grand Junction, Colorado, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Day.	Apr.	May.	June.	July.	Aug.	Sept.
1	2.00	4.60	6.60	5.60	3.00	1.80	17	3.90	7.30	7.20	3.80	2.70	1.80
2	2.10	4.50	6.50	5.40	4.30	1.90	18	4.20	7.00	7.10	3.80	2.60	1.90
3	2.00	4.40	6.40	5.60	3.10	1.80	19	4.30	7.10	7.20	3.70	2.60	2.10
4	2.00	4.00	6.00	5.60	3.80	1.90	20	4.50	7.30	7.30	3.90	2.50	2.00
5	2.00	4.00	5.60	5.40	4.00	1.90	21	4.20	7.00	7.20	3.80	2.40	1.80
6	2.00	4.00	5.50	5.00	3.60	1.90	22	3.90	6.50	7.10	3.70	2.40	1.60
7	2.10	4.10	5.50	4.90	3.40	2.00	23	4.20	5.80	6.80	3.60	2.20	1.60
8	2.10	4.30	5.80	4.20	3.90	1.90	24	4.70	5.90	6.50	3.50	2.10	1.60
9	2.20	4.80	5.90	4.20	3.20	1.60	25	5.00	6.20	6.40	3.30	2.00	1.60
10	2.30	5.20	6.00	4.10	3.20	1.50	26	5.40	6.40	6.40	3.20	1.80	1.50
11	2.60	5.80	6.50	4.00	3.00	1.50	27	5.70	6.50	6.50	3.00	1.80	1.40
12	2.80	6.30	6.90	3.90	2.70	1.40	28	5.60	6.70	6.10	3.30	1.80	1.40
13	3.00	6.60	7.30	3.90	2.70	1.40	29	5.40	6.50	5.80	3.60	1.80	1.40
14	3.40	7.20	7.50	4.00	2.70	1.60	30	5.00	6.40	5.70	3.30	1.80	1.30
15	3.60	7.40	7.50	4.00	2.70	1.80	31	.....	6.60	.....	3.20	2.10	.....
16	3.70	7.50	7.40	3.90	2.70	1.80							

Station discontinued September 30.

[Continued in Water-Supply and Irrigation Paper No. 38.]

O

56TH CONGRESS, 1st Session. } HOUSE OF REPRESENTATIVES. { DOCUMENT No. 724.

DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 38

OPERATIONS AT RIVER STATIONS, 1899.—PART IV

WASHINGTON
GOVERNMENT PRINTING OFFICE
1900

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

OPERATIONS AT RIVER STATIONS, 1899

A REPORT OF THE

DIVISION OF HYDROGRAPHY

OF THE

UNITED STATES GEOLOGICAL SURVEY

PART IV

WASHINGTON

GOVERNMENT PRINTING OFFICE

1900

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OPERATIONS AT RIVER STATIONS, 1899.

PART IV.

MEASUREMENTS AT RIVER STATIONS.[1]

DOLORES RIVER AT DOLORES, COLORADO.

This river is the last important tributary of Grand River. It has its source in the La Plata and San Miguel mountains, in which the highest peak, Mount Wilson, attains an elevation of 14,280 feet. Its course is in a general northwesterly direction. Crossing into Utah it shortly joins Grand River. In the vicinity of Dolores considerable irrigation is practiced, both from small ditches and from one or two large systems. The main canal of the Montezuma Valley irrigation system diverts water from the left bank of the river a short distance below the gaging station, and after crossing the divide between the Dolores and San Juan drainage irrigates land in the vicinity of Cortez. A lower lateral of this system serves land to the northwest of Dolores. The gaging station is located one-half mile above the railroad station at Dolores, Colorado. The gage rod consists of a vertical plank bolted to the abutment of a footbridge on the left side of the river. The bench mark consists of a nail driven into the base of a cottonwood tree 18 feet southwesterly from the gage, and is 15.60 feet above gage datum. The right bank is low and the left bank high; the water moves with a good velocity; the bed of the stream is composed of small stones and gravel. Dolores River at Rico, Colorado, was measured three times during the year: April 19 the discharge was 168 second-feet; September 22, 23 second-feet, and November 22, 16 second-feet. Results of measurements at this station may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 263; 1897, Nineteenth Annual Report, Part IV, page 408; 1898, Twentieth Annual Report, Part IV, page 393. The following discharge measurements were made by A. L. Fellows during 1899:

April 20, gage height, 3.60 feet; discharge, 613 second-feet.
May 17, gage height, 4.15 feet; discharge, 963 second-feet.
June 22, gage height, 3.30 feet; discharge, 307 second-feet.
November 22, gage height, 2.70 feet; discharge, 56 second-feet.

[1] Continued from Water-Supply and Irrigation Paper No. 37.

Daily gage height, in feet, of Dolores River at Dolores, Colorado, for 1899.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	2.60	3.05	3.75	3.10	2.95	2.65	2.50	2.80	2.55
2	.....	2.70	2.90	3.75	3.15	2.95	2.60	2.50	2.80	2.55
3	.....	2.70	3.15	3.55	3.25	3.50	2.60	2.50	2.70	2.55
4	.....	2.85	3.15	3.40	3.10	3.85	2.60	2.60	2.70	2.55
5	.....	2.85	3.80	3.40	3.10	3.60	2.50	2.60	2.70	2.75
6	.....	2.85	3.45	3.40	3.10	3.30	2.50	2.60	2.70	2.95
7	.....	2.95	3.70	3.65	3.10	3.70	2.50	2.50	2.70	3.00
8	.....	2.95	3.70	3.75	3.10	3.40	2.50	2.50	2.60	3.10
9	.....	3.05	3.60	3.85	3.00	3.25	2.50	2.50	2.60	3.10
10	.....	3.05	3.90	3.95	2.90	3.05	2.50	2.50	2.60	3.10
11	.....	3.20	4.10	3.90	2.90	3.00	2.50	2.50	2.60	3.10
12	.....	3.35	4.35	3.90	3.00	2.95	2.50	3.10	2.60	3.00
13	.....	3.25	4.65	3.85	3.15	2.90	2.50	3.30	2.60	3.00
14	.....	3.40	4.75	3.85	3.15	2.90	2.55	3.25	2.65	3.00
15	.....	3.60	4.75	3.70	3.10	2.95	2.80	3.00	2.70	3.00
16	.....	3.60	4.55	3.60	3.10	3.15	2.80	3.00	2.70	3.00
17	.....	3.60	4.15	3.50	3.10	3.15	2.70	3.00	2.70	3.05
18	.....	3.70	4.20	3.50	3.20	3.20	2.70	3.00	2.60	3.05
19	.....	4.05	4.40	3.50	3.40	3.05	2.65	3.00	2.60	3.05
20	.....	3.65	4.05	3.40	3.15	2.90	2.60	2.95	2.60	3.00
21	.....	3.55	3.60	3.30	3.10	2.90	2.60	2.85	2.60	3.00
22	2.40	3.85	3.70	3.30	3.00	2.85	2.55	2.80	2.60	3.00
23	2.40	3.90	3.85	3.25	3.00	2.75	2.50	2.80	2.70	3.00
24	2.40	4.00	4.15	3.20	2.95	2.70	2.50	2.75	2.70	2.95
25	2.50	4.05	4.00	3.20	2.90	2.70	2.50	2.70	2.70	2.95
26	2.80	4.00	4.00	3.25	2.85	2.60	2.50	2.70	2.70	2.90
27	2.55	3.90	3.85	3.40	2.90	2.60	2.50	2.70	2.65	3.00
28	2.75	3.75	3.80	3.25	2.90	2.60	2.50	2.70	2.65	3.00
29	2.60	3.55	3.80	3.10	3.00	2.60	2.50	2.70	2.65	3.00
30	2.65	3.20	3.85	3.10	3.25	2.60	2.50	2.70	2.65	3.00
31	2.50	.....	3.85	.....	3.15	2.55	.....	2.80	.....	3.05

SAN MIGUEL RIVER AT FALLCREEK, COLORADO.

This river has its source in the high mountain peaks in the southwestern corner of San Miguel County, and drains an area immediately to the westward of the head waters of Uncompahgre River. The general direction of the river is northeasterly, and it enters Dolores River in the western part of Montrose County, Colorado. The station, established in June, 1895, is located about 300 yards southwest of Fallcreek, a railroad station on the Rio Grande Southern Railroad. The gage is vertical and spiked to the west side of the north abutment of the wagon bridge. Bench mark No. 1 is a bolthead in the north end of the west truss, 1 foot from the gage, and is 11.15 feet above gage datum. Bench mark No. 2 is a spike driven into a tree 200 feet northwest of the rod, and is 8.65 feet above gage datum. Fall Creek enters the San Miguel about 200 feet below the gage. On May 16, 1899, it was found to be carrying 62 second-feet, and on June 21, 45 second-feet. The results of measurements on the main river may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 265; 1897, Nineteenth Annual Report, Part IV, page 407; 1898, Twentieth Annual Report, Part IV, page 395. The following measurements of discharge were made by A. L. Fellows during 1899:

April 18, gage height, 2.85 feet; discharge, 164 second-feet.
May 16, gage height, 3.70 feet; discharge, 562 second-feet.
June 21, gage height, 3.60 feet; discharge, 449 second-feet.
November 21, gage height, 2.35 feet; discharge, 52 second-feet.

Daily gage height, in feet, of San Miguel River at Fallcreek, Colorado, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Day.	Apr.	May.	June.	July.	Aug.	Sept.
1....	2.30	2.80	3.50	3.35	2.90	2.60	17.....	2.85	3.65	3.85	3.00	2.90	2.60
2....	2.20	2.75	3.45	3.50	3.20	2.60	18.....	2.90	3.80	3.85	3.35	2.90	2.60
3....	2.30	2.75	3.40	3.40	3.50	2.65	19.....	2.95	3.70	3.90	3.25	3.00	2.60
4....	2.30	2.70	3.30	3.30	3.35	2.65	20.....	2.95	3.60	3.80	3.05	2.85	2.55
5....	2.25	2.80	3.15	3.20	3.35	2.55	21.....	2.80	3.30	3.75	3.00	2.75	2.60
6....	2.30	2.80	3.25	3.10	3.35	2.60	22.....	2.85	3.20	3.70	3.00	2.70	2.60
7....	2.30	3.00	3.25	3.05	3.35	2.60	23.....	3.20	3.40	3.45	2.95	2.70	2.50
8....	2.40	3.00	3.30	3.00	3.25	2.60	24.....	3.20	3.50	3.35	2.95	2.80	2.60
9....	2.40	3.00	3.75	3.00	3.15	2.60	25.....	3.30	3.55	3.30	3.00	2.70	2.60
10....	2.50	3.20	4.05	3.05	3.00	2.60	26.....	3.20	3.50	3.35	2.95	2.65	2.60
11....	2.45	3.40	4.05	3.05	2.90	2.55	27.....	3.05	3.55	3.30	3.00	2.60	2.60
12....	2.50	3.75	3.95	3.15	3.00	2.40	28.....	2.90	3.55	3.30	3.00	2.60	2.60
13....	2.70	3.95	3.90	3.20	3.00	2.40	29.....	2.80	3.55	3.35	3.10	2.60	2.50
14....	2.70	4.00	4.00	3.25	3.00	2.70	30.....	2.90	3.80	3.30	3.00	2.60	2.40
15....	2.80	3.90	4.00	3.10	3.00	2.75	31.....	.....	3.80	.....	2.90	2.60	.....
16....	2.75	3.80	3.90	3.00	2.95	2.65							

Station discontinued September 30.

SAN JUAN RIVER AT ARBOLES, COLORADO.

This river has its source on the western slope of the Continental Divide in southern Colorado, its headwater tributaries adjoining those of the Rio Grande. Its general direction is southwesterly, but after it receives the waters of Piedra River and crosses the State line into New Mexico, it takes a more westerly direction for some distance, then turns northwest, passing very close to the four corners of Utah, Colorado, New Mexico, and Arizona. After flowing for a considerable distance through a canyon country in Utah, it enters Colorado River a short distance above Marble Canyon. The gaging station, established June 19, 1895, is located at the town of Arboles, at a footbridge about 1,000 feet below the Rio Grande Southern railroad station and above the mouth of Piedra River. The rod is an inclined timber marked to vertical tenths of a foot, the space between marks being 0.131 foot, and is bolted to the rocky bank on the right-hand side of the stream. The left bank is low and liable to overflow at high stages. The bed is sandy and shifting. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 281; 1897, Nineteenth Annual Report, Part IV, page 410; 1898, Twentieth Annual Report, Part IV, page 401. The following measurements of discharge were made by A. L. Fellows during 1899:

April 23, gage height, 7 feet; discharge, 1,286 second-feet.
May 22, gage height, 6.60 feet; discharge, 737 second-feet.
June 26, gage height, 6.15 feet; discharge, 277 second-feet.
November 26, gage height, 5.75 feet; discharge, 127 second-feet.

Daily gage height, in feet of San Juan River at Arboles, Colorado, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Day.	Apr.	May.	June.	July.	Aug.	Sept.
1	.....	6.40	6.65	6.05	6.25	5.70	17	.....	6.85	6.35	6.60	6.10	6.20
2	.....	6.35	6.55	6.00	6.15	5.70	18	.....	6.85	6.35	7.25	6.15	6.10
3	.....	6.30	6.55	6.05	7.25	5.70	19	.....	7.00	6.30	7.40	5.95	6.00
4	.....	6.30	6.50	6.00	7.30	5.70	20	.....	6.85	6.25	7.25	5.90	6.00
5	.....	6.30	6.50	6.05	6.95	5.70	21	.....	6.60	6.30	7.10	5.85	6.00
6	.....	6.25	6.50	5.95	6.60	5.65	22	.....	6.55	6.35	6.70	5.80	5.90
7	.....	6.35	6.55	6.25	6.65	5.60	23	7.00	6.75	6.30	6.40	5.85	5.85
8	.....	6.45	6.65	6.20	6.55	5.60	24	6.95	6.85	6.20	6.35	5.85	5.80
9	.....	6.40	6.60	6.10	6.35	5.70	25	6.90	6.85	6.20	6.20	5.80	5.80
10	.....	6.50	6.65	6.00	6.30	5.70	26	6.80	6.80	6.25	6.15	5.80	5.80
11	.....	6.80	6.65	5.95	6.20	5.70	27	6.75	6.85	6.35	6.20	5.80	5.70
12	.....	7.10	6.60	5.85	6.05	5.70	28	6.55	6.75	6.20	6.30	5.70	5.70
13	.....	7.50	6.55	5.90	5.95	5.60	29	6.50	6.65	6.10	6.60	5.70	5.70
14	.....	7.30	6.50	5.85	5.90	5.65	30	6.45	6.65	6.15	6.70	5.70	5.70
15	.....	7.25	6.50	5.95	5.90	7.40	31	.....	6.75	.....	6.55	5.70	.....
16	.....	7.00	6.45	6.00	5.95	6.65							

Station discontinued September 30.

PIEDRA RIVER AT ARBOLES, COLORADO.

This tributary of San Juan River has its source in Hinsdale and Mineral counties in southern Colorado, and flows in a general southerly direction, entering San Juan River just before the latter crosses into New Mexico. The station, established June 19, 1895, is located at the railroad bridge crossing Piedra River about one-half mile west of the railroad station at Arboles. The gage is bolted to the stone abutment of the railroad bridge on the right-hand side of the stream, and consists of a vertical 4 by 4 inch timber. The bench mark is a cross cut in the top of abutment in the southeast corner of bridge 402–A, and is 14.88 feet above gage datum. The banks are both high, the current is swift, and the bed is composed of small stones. The cross section does not change materially. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 283; 1897, Nineteenth Annual Report, Part IV, page 413; 1898, Twentieth Annual Report, Part IV, page 402. The following measurements were made by A. L. Fellows during 1899:

April 23, gage height, 3.80 feet; discharge, 499 second-feet.
May 22, gage height, 3.40 feet; discharge, 279 second-feet.
June 26, gage height, 2.90 feet; discharge, 111 second-feet.
November 26, gage height, 2.80 feet; discharge, 88 second-feet.

Daily gage height, in feet, of Piedra River at Arboles, Colorado, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Day.	Apr.	May.	June.	July.	Aug.	Sept.
1	.....	3.25	3.30	2.85	3.05	2.50	17	.....	3.75	3.00	2.90	2.85	2.90
2	.....	3.20	3.20	2.85	3.00	2.50	18	.....	3.65	2.95	3.10	2.80	2.80
3	.....	3.05	3.25	3.00	4.05	2.50	19	.....	3.75	2.90	3.75	2.80	2.70
4	.....	3.00	3.20	2.95	4.45	2.50	20	.....	3.55	2.90	3.55	2.80	2.60
5	.....	3.00	3.15	2.90	3.75	2.50	21	.....	3.35	2.90	3.45	2.75	2.50
6	.....	3.05	3.20	2.80	3.75	2.50	22	.....	3.40	2.90	3.20	2.70	2.50
7	.....	3.10	3.30	3.05	3.60	2.40	23	3.80	3.35	2.95	3.00	2.70	2.50
8	.....	3.20	3.35	2.95	3.50	2.40	24	3.75	3.45	2.80	2.90	2.70	2.50
9	.....	3.25	3.35	2.95	3.35	2.50	25	3.75	3.50	2.80	2.80	2.70	2.50
10	.....	3.30	3.35	2.80	3.20	2.60	26	3.70	3.40	2.85	2.80	2.70	2.50
11	.....	3.65	3.30	2.85	3.15	2.60	27	3.65	3.45	3.25	2.75	2.65	2.50
12	.....	4.05	3.25	2.65	3.00	2.50	28	3.55	3.45	3.05	2.80	2.60	2.50
13	.....	4.10	3.15	2.75	2.90	2.50	29	3.45	3.30	2.90	3.05	2.60	2.45
14	.....	3.95	3.10	2.80	2.90	2.55	30	3.35	3.35	2.85	3.20	2.50	2.40
15	.....	4.05	3.10	2.85	2.90	2.95	31	.....	3.30	.....	3.15	2.50	.....
16	.....	3.90	3.05	2.85	2.90	3.00							

Station discontinued September 30.

LOS PINOS RIVER AT IGNACIO, COLORADO.

This stream heads in the high mountains of San Juan County in southwestern Colorado, and flows in a nearly southerly direction, crossing the State line into New Mexico and emptying into San Juan River. The station was established by A. L. Fellows on April 22, 1899, and is located at the wagon bridge at Ignacio, the subagency of the Southern Ute Indian Reservation, 2 miles north of the Denver and Rio Grande railroad station. The rod is a vertical 2 by 4 inch timber, 10 feet long, spiked to the bridge, the marks being strips of brass securely nailed to the post. There is one bench mark, the 8-foot mark on the gage rod, which is level with the top of the lower end of a 6 by 8 inch timber protruding downstream from the pier on the right-hand side. The banks are low, but not subject to overflow; the bed of the stream is of gravel, but not liable to radical change. The observer is the clerk at the agency. The following measurements were made by A. L. Fellows during 1899:

April 22, gage height, 3.20 feet; discharge, 437 second-feet.
May 20, gage height, 3.40 feet; discharge, 577 second-feet.
June 25, gage height, 2.80 feet; discharge, 244 second-feet.
November 25, gage height, 2.60 feet; discharge, 124 second-feet.

Daily gage height, in feet, of Los Pinos River at Ignacio, Colorado, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	2.90	3.35	2.95	3.05	2.30	2.30	2.50	2.50
2	.....	2.90	3.25	2.95	3.40	2.30	2.25	2.50	2.50
3	.....	2.80	3.15	2.95	4.05	2.30	2.20	2.50	2.50
4	.....	2.80	3.10	2.95	4.75	2.29	2.45	2.50	2.45
5	.....	2.75	3.00	2.80	3.90	2.25	2.50	2.50	2.40
6	.....	2.70	3.05	2.80	3.60	2.20	2.40	2.50	2.40
7	.....	2.70	3.15	2.80	3.55	2.29	2.40	2.50	2.40
8	.....	2.85	3.30	2.80	3.50	2.25	2.30	2.50	2.30
9	.....	2.90	3.35	2.75	3.35	2.25	2.30	2.50	2.30
10	.....	3.05	3.35	2.70	3.20	2.25	2.30	2.50	2.30
11	.....	3.55	3.40	2.70	3.00	2.29	2.25	2.50	2.30
12	.....	3.85	3.45	2.65	2.95	2.30	2.55	2.50	2.30
13	.....	4.05	3.40	2.60	2.90	2.39	2.70	2.50	2.30
14	.....	3.95	3.45	2.70	2.85	2.30	2.90	2.50	2.30
15	.....	3.85	3.45	2.70	2.80	2.85	2.85	2.60	2.30
16	.....	3.75	3.35	2.70	2.90	2.65	2.80	2.60	2.30
17	.....	3.60	3.25	2.70	2.90	2.45	2.60	2.60	2.30
18	.....	3.60	3.20	2.80	2.90	2.40	2.70	2.60	2.30
19	.....	3.80	3.20	3.55	2.85	2.40	2.70	2.60	2.30
20	.....	3.50	3.15	3.30	2.75	2.40	2.70	2.60	2.30
21	.....	3.25	3.10	3.10	2.65	2.40	2.70	2.60	2.30
22	.....	3.20	3.05	3.05	2.60	2.40	2.70	2.60	Ice.
23	3.40	3.30	2.95	2.95	2.55	2.40	2.70	2.60	Ice.
24	3.50	3.55	2.90	2.85	2.50	2.30	2.70	2.60	Ice.
25	3.50	3.55	2.85	2.80	2.45	2.30	2.65	2.60	Ice.
26	3.40	3.35	3.25	2.80	2.40	2.30	2.60	2.60	Ice.
27	3.20	3.35	3.45	2.80	2.40	2.30	2.60	2.50	Ice.
28	3.20	3.30	3.25	2.80	2.40	2.30	2.60	2.50	Ice.
29	3.00	3.35	3.15	3.15	2.35	2.30	2.50	2.50	Ice.
30	2.90	3.35	3.05	3.35	2.30	2.30	2.30	2.50	Ice.
31	.....	3.45	.....	3.20	2.30	.....	2.50	.....	Ice.

ANIMAS RIVER AT DURANGO, COLORADO.

This river is an important tributary of the San Juan, and has its source in the high peaks of southwestern Colorado. It has a nearly southerly course, crossing the State line into New Mexico, where it shortly enters San Juan River. The station originally established June 20, 1895, was located at the wagon bridge one-quarter of a mile west of the railroad station at Durango, and about 200 feet above the Rio Grande Southern railroad bridge. During the early part of the year the old wagon bridge was removed and a new one erected a short distance below. April 1, 1899, a gage rod was placed on the central pier of the new bridge. The bench marks are three horizontal strips, opposite the 10-, 14-, and 16.7-foot marks of the rod, respectively. Owing to this change in location and height of the rod there is no apparent relation between the rating tables for past years and the rating table for 1899. Lightner Creek enters Animas River from the right about 100 feet below the wagon bridge. The channel is straight both above and below the station, and the bed is of gravel and fairly permanent. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 285; 1897, Nineteenth Annual Report, Part IV, page 414; 1898, Twentieth Annual Report, Part IV, page 403. Measurements for 1899 were made by A. L. Fellows, as follows:

April 21, gage height, 7.50 feet; discharge, 698 second-feet.
May 19, gage height, 9.45 feet; discharge, 2,635 second-feet.
June 24, gage height, 8.10 feet; discharge, 1,256 second-feet.
September 28, gage height, 6.52 feet; discharge, 223 second-feet.
November 25, gage height, 6.50 feet; discharge, 201 second-feet.

Daily gage height, in feet, of Animas River at Durango, Colorado, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	6.45	7.40	9.20	7.80	7.05	6.85	6.50	6.80	.....
2	6.50	7.35	8.75	7.85	7.25	6.80	.....	.....	6.40
3	6.45	7.35	8.35	8.05	8.20	6.80	.....	.....	.....
4	6.35	7.35	8.05	7.75	8.90	6.75	.....	6.70	6.40
5	6.35	7.35	7.75	7.65	8.45	6.70	.....	.....	.....
6	6.30	7.25	7.90	7.60	8.15	6.70	.....	.....	.....
7	6.35	7.25	8.20	7.65	8.15	6.65	6.50	6.80	.....
8	6.40	7.50	8.45	7.50	8.00	6.70	.....	.....	.....
9	6.45	7.65	8.70	7.45	7.70	6.70	.....	.....	6.40
10	6.50	7.80	9.15	7.45	7.55	6.65	.....	6.70	.....
11	6.70	8.60	9.30	7.30	7.45	6.60	6.80	.....	.....
12	6.80	9.40	9.60	7.35	7.35	6.60	.....	.....	6.50
13	7.00	9.85	9.65	7.40	7.30	6.60	.....	.....	.....
14	7.10	10.00	9.55	7.40	7.20	6.60	6.90	6.70	.....
15	7.30	9.80	9.45	7.40	7.20	6.90	.....	.....	.....
16	7.55	9.60	9.25	7.35	7.35	6.95	.....	.....	6.70
17	7.50	9.50	9.15	7.20	7.55	6.90	6.80	.....	.....
18	7.65	9.35	9.10	7.25	7.45	6.80	.....	6.70	.....
19	7.75	9.40	8.85	7.90	7.30	6.80	.....	.....	.....
20	7.65	9.05	8.75	7.75	7.25	6.75	.....	.....	.....
21	7.45	8.20	8.65	7.45	7.20	6.70	6.80	6.70	.....
22	7.55	8.05	8.55	7.35	7.10	6.70	.....	.....	6.60
23	7.95	8.10	8.35	7.30	7.05	6.70	.....	.....	.....
24	8.05	8.90	8.10	7.20	7.00	6.60	6.90	.....	.....
25	8.10	9.00	8.00	7.15	6.95	6.60	.....	6.50	.....
26	8.00	8.80	8.25	7.10	6.90	6.60	.....	.....	6.70
27	7.95	8.90	8.25	7.10	6.90	6.60	.....	.....	.....
28	7.85	8.50	8.00	7.00	6.85	6.60	6.80	.....	.....
29	7.65	8.80	7.95	7.00	6.80	6.55	.....	6.50	6.50
30	7.45	9.30	7.80	7.20	6.80	6.50	.....	.....	.....
31	.....	9.35	.....	7.15	6.80	.....	.....	.....	.....

FLORIDA RIVER NEAR DURANGO, COLORADO.

This stream is a tributary of Animas River, and rises in the northern part of La Plata County; flowing in a general southerly direction it enters Animas River a short distance before this latter stream passes into New Mexico. During the last season work has been prosecuted on a large storage project near the head of the river, and on this account a gaging station was established by A. L. Fellows May 19, 1899. It is located at a wagon bridge at Stewart's ranch, 9 miles east of Durango. The gage rod consists of a vertical 2 by 4 inch timber fastened to the downstream side of the left-hand abutment of the bridge. In 1899 two measurements of discharge were made at this point by A. L. Fellows. The first, on May 19, at a gage height of 2.25 feet, showed a discharge of 236 second-feet; the second, on June 24, at a gage height of 0.70 feet, showed a discharge of 9 second-feet.

Daily gage height, in feet, of Florida River near Durango, Colorado, for 1899.

Day.	May.	June.	July.	Day.	May.	June.	July.	Day.	May.	June.	July.
1	.....	1.65	1.05	12	.....	1.70	0.65	23	1.90	0.75	1.00
2	.....	1.50	.95	13	.....	1.60	.70	24	2.05	.75	.95
3	.....	1.35	1.05	14	.....	1.60	.85	25	2.00	.75	.80
4	.....	1.25	.95	15	.....	1.45	.65	26	1.80	1.25	.95
5	.....	1.20	.95	16	.....	1.30	.65	27	1.80	1.60	1.10
6	.....	1.40	.90	17	.....	1.25	.70	28	1.65	1.35	1.25
7	.....	1.60	.65	18	.....	1.15	1.60	29	1.75	1.10	2.15
8	.....	1.70	.75	19	.....	1.15	1.85	30	1.70	1.00	1.90
9	.....	1.70	.70	20	.....	1.05	1.45	31	1.80	.....	1.60
10	.....	1.60	.75	21	1.65	1.00	1.25				
11	.....	1.55	.65	22	1.60	.95	1.05				

Station discontinued July 31.

MANCOS RIVER AT MANCOS, COLORADO.

This river is an important tributary of the San Juan, draining the southwestern corner of Colorado. The lower portion of its course is through the Southern Ute Indian Reservation. It enters San Juan River near the adjoining corners of Utah, Colorado, New Mexico, and Arizona. The primary object of a station on this river was to obtain data relative to the amount of water that can be stored for the water supply of the Southern Ute Indian Reservation. The results of this investigation, made by Mr. G. H. Matthes, may be found in the Twentieth Annual Report, Part IV, pages 408 to 434. The gaging station, established by A. L. Fellows April 9, 1898, is located 100 feet below the wagon bridge across the river in the center of the town of Mancos. The gage consists of a vertical timber spiked to a cottonwood tree on the left bank of the river. Measurements are usually made by wading, but the wagon bridge can be used at high stages of water. The banks are not subject to overflow. The channel is in gravel, but is not liable to radical change. The results of measurements in 1898 may be found in the Twentieth Annual Report, Part IV, page 404. The following measurements of discharge were made by A. L. Fellows during 1899:

April 19, gage height, 1.65 feet; discharge, 70 second-feet.
May 18, gage height, 1.60 feet; discharge, 56 second-feet.
June 23, gage height, 1.10 feet; discharge, 9 second-feet.
September 22, gage height, 0.90 foot; discharge, 2 second-feet.
November 24, gage height, 1 foot; discharge, 3 second-feet.

Daily gage height, in feet, of Mancos River at Mancos, Colorado, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	.....	1.50	1.70	1.10	1.20	1.00	1.40	1.10
2	.....	1.40	1.70	1.00	1.20	1.00	1.40	1.10
3	.....	1.40	1.70	1.10	1.40	1.00	1.30	1.10
4	.....	1.40	1.60	1.10	1.60	1.00	1.30	1.10
5	.....	1.30	1.50	1.10	1.60	1.00	1.30	.....
6	.....	1.40	1.50	1.10	1.70	1.00	1.20	.....
7	.....	1.40	1.50	1.10	1.50	1.00	1.00	.....
8	.....	1.40	1.50	1.10	1.60	1.00	1.50	.....
9	1.00	1.50	1.60	1.00	1.60	1.00	1.60	.....
10	1.10	1.50	1.60	1.00	1.70	1.10	1.50	.....
11	1.00	1.75	1.60	1.00	1.70	1.10	1.50	.....
12	1.00	1.80	1.50	1.00	1.80	1.10	1.50	.....
13	1.00	2.00	1.50	.90	1.80	1.10	1.50	.....
14	1.00	2.00	1.50	1.00	1.70	1.00	1.50	.....
15	1.00	1.90	1.50	1.00	1.60	1.00	1.50	.....
16	1.50	1.80	1.50	1.00	1.60	1.00	1.50	.....
17	1.60	1.80	1.50	1.10	1.50	1.00	1.40	.....
18	1.55	1.80	1.10	1.30	1.50	1.00	1.40	.....
19	1.65	1.80	1.10	1.30	1.40	1.90	1.30	.....
20	1.50	1.80	1.10	1.30	1.40	1.90	1.30	.....
21	1.50	1.60	1.00	1.30	1.30	1.90	1.20	.....
22	1.50	1.70	1.00	1.30	1.30	1.70	1.10	.....
23	1.70	2.00	1.00	1.20	1.20	1.70	1.00	.....
24	1.75	1.50	1.00	1.20	1.20	1.60	1.00	.....
25	1.70	1.55	1.00	1.10	1.10	1.60	1.00	.....
26	1.70	1.80	1.20	1.00	1.10	1.60	.90	.....
27	1.70	1.80	1.20	1.00	1.10	1.50	.90	.....
28	1.50	1.70	1.10	1.00	1.10	1.50	.80	.....
29	1.50	1.70	1.10	1.00	1.10	1.50	.80	.....
30	1.50	1.60	1.10	1.10	1.10	1.50	1.10	.....
31	.....	1.65	.....	1.10	1.15	.....	1.10	.....

Closed for the winter November 4.

GILA RIVER AT SAN CARLOS, ARIZONA.

This river rises in southwestern New Mexico and has a general southwesterly direction until it crosses the territorial line into Arizona at about 32° 40′ north latitude. Its principal sources of supply are from the Black Range on the east, and from a number of ranges on the west, including Little Range, Mogollon Range, and Diablo Range. The average elevation of these mountain peaks is from 9,000 to 10,000 feet. The general character of the country is a high and rolling plateau, with the river flowing through it in a deep canyon, and with practically no agricultural lands within its area. The river emerges from its upper canyon about 10 miles before it reaches the Arizona line, and thence flows through a valley of considerable width, known as Duncan Valley, until just before it receives the waters of San Francisco River. Duncan Valley, in which a number of ditches divert water for irrigation purposes, will be described at length in the Twenty-first Annual Report. San Francisco River, the principal tributary of the upper Gila, has it source in the northeast corner of Graham County, Arizona, but 15 miles below it passes into New Mexico. Its general course is thence southerly, returning into Arizona at about 33° north latitude. The area drained is high and mountainous, the principal ranges being the San Francisco, the Tularosa, and the western slope of the Mogollon, with elevations ranging from 8,000 to 10,000 feet. The course of the river through this portion is characterized by a succession of canyons alternating with valley-like openings, with the considerable fall of from 35 to 40 feet per mile.

Gila River is in canyon for about 20 miles below the mouth of the San Francisco, or to within 10 miles of Solomonsville. At this point the hills separate, forming a large valley which has been extensively settled and is now one of the finest irrigated portions of the Territory. The results of a series of seepage measurements made from 10 miles above Solomonsville down to Fort Thomas, with a description of the irrigation enterprises in this section, will be published in the Twenty-first Annual Report. This valley extends from a point 10 miles above Solomonsville to 6 miles below the mouth of San Carlos River on the White Mountain Indian Reservation. At this latter place the mountains suddenly close in again, and the river enters another canyon. Seven miles below the Indian agency at San Carlos the canyon boxes to a width of 100 feet, and at this point is located the San Carlos dam site, which was studied in detail by the United States Geological Survey during 1899, in connection with the investigation of the water supply of Gila River. The results of this investigation are published in Water-Supply and Irrigation Paper No. 33, entitled Storage of Water on Gila River, Arizona, by J. B. Lippincott. In connection with this investigation Cyrus C. Babb, on July 11, 1899, established a

station on Gila River one-half mile south of the Indian agency at San Carlos and below the mouth of San Carlos Creek. An inclined rod securely fastened to posts driven into the bank was erected here. The bench mark is a 20-penny nail in the base of a mesquite tree 5 inches in diameter, 85 feet west of the gage rod, at an elevation of 12.67 feet above gage datum. Discharge measurements are made from a cable and car a short distance above the gage rod. The channel is straight for some distance above and below the station, and the water is comparatively swift. The right bank is high, but the left is low and liable to overflow. The bed of the stream is sandy and shifting. The following measurements of discharge were made by Cyrus C. Babb and Stephen Janus during 1899:

Discharge measurements of Gila River at San Carlos, Arizona.

1899.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
August 4	3.63	1,038	September 14	2.10	312
September 6	2.30	170	September 19	1.90	127
September 7	3.20	849	September 29	1.50	77
September 8	5.45	8,458	October 6	2.30	215
September 9	3.60	2,130	October 14	1.80	108

Daily gage height, in feet, of Gila River at San Carlos, Arizona, for 1899.

Day.	July.	Aug.	Sept.	Oct.	Day.	July.	Aug.	Sept.	Oct.	Day.	July.	Aug.	Sept.	Oct.
1	.....	3.10	1.60	1.50	12	3.10	2.40	2.38	1.90	23	3.50	1.70	1.70	.....
2	.....	3.90	1.60	1.50	13	2.70	2.40	2.30	1.85	24	3.40	1.70	1.70	.....
3	.....	3.20	1.60	1.50	14	2.50	2.20	2.13	1.80	25	3.20	1.70	1.70	.....
4	.....	3.10	1.60	1.60	15	2.20	2.20	2.00	.....	26	3.10	1.70	1.70	.....
5	.....	2.80	1.55	1.60	16	2.30	2.00	2.00	.....	27	3.13	1.69	1.69	.....
6	.....	2.80	2.05	2.40	17	2.10	2.00	2.00	.....	28	3.07	1.60	1.60	.....
7	.....	2.90	2.60	2.30	18	2.30	1.80	2.00	.....	29	3.20	1.85	1.50	.....
8	.....	2.70	5.25	2.30	19	6.50	1.80	1.90	.....	30	2.90	1.60	1.50	.....
9	.....	3.00	3.10	2.00	20	4.90	1.80	1.85	.....	31	2.80	1.60	.....	.....
10	.....	2.80	2.80	1.90	21	3.60	1.80	1.80	.....					
11	4.00	2.50	2.60	1.90	22	3.50	1.80	1.70	.....					

Station discontinued October 14.

The following measurements were made by Cyrus C. Babb during a reconnaissance trip through the upper basin of Gila River in the spring of 1899. The measurements from March 11 to 17, inclusive, are of San Pedro River and of the ditches diverting water from it. The measurements on March 29, 30, and 31 were made on the ditches diverting water from Gila River above Duncan, Arizona. The measurements from April 15 to 17, inclusive, were made principally on ditches diverting water from Gila River in the Solomonsville Valley, and were made to determine the amount of seepage water returning to the stream. A discussion of these latter measurements will be made in the Twenty-first Annual Report, Part IV.

Miscellaneous discharge measurements in Gila River Basin, Arizona.

1893.

Date.	Stream.	Locality.	Discharge.
			Second-feet.
March 11	Gila River	Above mouth of San Pedro	62.0
March 11	San Pedro River	Dudleyville	9.6
March 11	Burns and Lopez ditch.	Dudleyville	4.6
March 12	Scott and Cunningham ditch.	Dudleyville	6.6
March 12	San Pedro River	Below Scott and Cunningham ditch.	1.0
March 12	Swingle ditch	At head on San Pedro River.	3.7
March 12	Finch and Draper ditch.	At head on San Pedro River.	2.8
March 13	Dodson ditch	At head on San Pedro River.	7.6
March 13	San Pedro River	Below Dodson ditch	0.0
March 13	Cook ditch	At head on San Pedro River.	6.4
March 13	Busand ditch	At head on San Pedro River.	3.4
March 13	San Pedro River	1 mile below Mammoth	0.0
March 14	Brown ditch	At head on San Pedro River.	9.1
March 14	Clark ditch	At head on San Pedro River.	2.3
March 14	San Pedro River	Pinal and Pima counties line.	1.5
March 15	San Pedro River	Narrows	5.1
March 15	Los Angeles ditch	At head on San Pedro River.	4.2
March 16	San Pedro River	Line between townships 14 and 15 south.	10.0
March 17	St. David canal	2 miles above St. David	7.3
March 17	San Pedro River	Benson, Arizona, ½ mile below railroad.	6.5
March 17	Etts ditch	1 mile below railroad at Benson.	1.2
March 17	San Pedro River	5 miles south of Benson	5.7
March 22	Union ditch	Solomonsville	76.0
March 22	Gila River	Below head of Union ditch, Solomonsville.	10.0
March 29	Gila River	Below Telles ditch	156.0
March 30	Telles ditch	Above Duncan	4.0
March 30	Rucker ditch	Above Duncan	1.6
March 30	Hughes ditch	Above Duncan	2.8
March 30	Martin ditch	Above Duncan	3.0
March 30	Wilson ditch	Above Duncan	4.7
March 30	Casper and Windham ditch.	Above Duncan	6.8
March 30	Johnson ditch	Above Duncan	0.7
March 30	Schriver ditch	Above Duncan	6.2
March 30	Franklin ditch	Above Duncan	13.9
March 30	Valley canal	Above Duncan	22.9
March 30	Owens canal	Above Duncan	1.8
March 30	Day's ditch	Above Duncan	6.0
March 31	Ward and Courtney ditch.	Above Duncan	7.8
March 31	Black and McCloskey ditch.	Above Duncan	3.8
March 31	Gila River	Duncan	104.0
April 5	San Francisco River	7 miles above Clifton	94.0
April 5	Blue River	At mouth	43.0
April 5	San Francisco River	Above mouth of Blue River.	54.0
April 13	San Francisco River	Flume power house, below Clifton.	92.0
April 14	Gila Piver	5 miles above San Francisco River.	95.0
April 15	Brown ditch	Near head	0.6

Miscellaneous discharge measurements in Gila River Basin, Arizona—Continued.

1899—Continued.

Date	Stream.	Locality.	Discharge.
			Second-feet.
April 15	Sanchez ditch	Near head	7.6
April 15	Gila River	Narrows below Sanchez ditch	237.0
April 15	Mejia ditch	Below waste	4.3
April 15	Old San Jose ditch	Near head	11.6
April 15	San Jose ditch	Near head	45.0
April 15	Gila River	Below San Jose ditch	189.0
April 15	Waste	North side	2.0
April 15	Michelena ditch	Below waste gate	9.4
April 15	Montezuma ditch	Below waste gate	101.0
April 15	Gonzales ditch	Below waste gate	4.0
April 15	Gila River	Below Gonzales ditch	63.0
April 15	Waste	Montezuma ditch	27.0
April 15	Waste	Above Union ditch	10.0
April 15	Union ditch	At head	93.0
April 15	Gila River	Below Union ditch	10.4
April 16	Lee ditch	At head	3.3
April 16	Sunflower ditch	At head	4.9
April 16	Graham ditch	At head	18.6
April 16	Central ditch	At head	19.5
April 16	Gila River	Below Central ditch	6.8
April 16	Oregon ditch	At head	11.1
April 16	Smithville ditch	At head	13.2
April 16	Gila River	Below Smithville ditch	1.5
April 16	Brice ditch	At head	7.4
April 16	Dodge ditch	At head	6.7
April 17	Mathewsville ditch	At head	33.0
April 17	Gila River	Below Mathewsville ditch	2.8
April 17	Curtis ditch	At head	14.3
April 17	Gila River	Below Curtis ditch	0.0
April 17	Kempton ditch	At head	9.3
April 17	Vogel ditch	At head	0.0
April 17	Gila River	Below Vogel ditch	7.0
April 17	Reid ditch	At head	3.8
April 17	Gila River	Below Reid ditch	10.8
April 17	Fort Thomas ditch	At head	3.7
April 17	Upper Thompson ditch.	At head	0.0
April 17	Lower Thompson ditch.	At head	5.3
April 17	Military ditch	Flume at Fort Thomas	5.9
April 17	Saline ditch	At head	0.7
April 17	Mexican ditch	At head	0.8
April 17	Gila River	Opposite Fort Thomas	20.0
April 17	Gila River	3 miles below Fort Thomas	32.8
April 25	Indian ditch	San Carlos	12.2
April 28	Gila River	San Carlos Canyon	27.0
May 15	Gila River	Duncan	10.0
May 24	Gila River	San Carlos Canyon	7.0

GILA RIVER AT THE BUTTES, ARIZONA.

Gila River is in canyon from a short distance below the mouth of San Carlos River to about the mouth of San Pedro River, a distance of 31 miles. The country then broadens into a valley of considerable size, extending for a distance of about 20 miles, to below the mouth of Mineral Creek. This opening, known as Riverside Valley, was examined in detail in connection with the investigation of the water

supply of Gila River, and the lower portion was mapped by G. H. Matthes as a reservoir site. From the mouth of Mineral Creek the river is in canyon again until what is known as the Buttes are reached—a distance of about 15 miles, when the river appears on the Great Plains region of southwestern Arizona. Its general course is thence westerly until it enters the Colorado River at Yuma. The present station at the Buttes was established February 20, 1896, in connection with the first investigation for a water supply for the Gila River Indian Reservation. It is located about 16 miles above Florence, Arizona. The gage rod is bolted to a solid rock on the right bank where the river emerges from the lower end of the gorge. The bench mark is a rock point chiseled on a ledge 69.4 feet southeast of the south cable support and 4.4 feet above the ground, and is at an elevation of 1,608.45 feet above sea level. The elevation of the zero of the rod is 1,583.00 feet. Measurements at this point were made in connection with the investigation of the water supply of the Gila River by the United States Geological Survey, authorized by special act of Congress. The results of the work are published in Water-Supply and Irrigation Paper No. 33, entitled Storage of Water on Gila River, Arizona, by J. B. Lippincott. The channel of the river at the Buttes is composed of quicksand and likely to change daily with any considerable amount of water in the river. In order to obtain an accurate estimate of the daily discharge, it is necessary to make continuous measurements, which was done during the investigation. The results of the measurements at this point will be found as follows: 1896, Eighteenth Annual Report, Part IV, page 290; 1897, Nineteenth Annual Report, Part IV, page 416; 1898, Twentieth Annual Report, Part IV, page 405; 1899, Water-Supply and Irrigation Paper No. 33, page 26. The following measurements of discharge were made during 1899 by various members of the United States Geological Survey connected with the water-supply investigation:

Discharge measurements of Gila River at the Buttes, Arizona.

1899.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
January 14	3.20	634	March 4	2.50	139
January 25	2.75	245	March 6	2.50	123
February 3	2.90	616	March 8	2.50	142
February 3	2.86	547	March 10	2.50	146
February 4	2.90	514	March 13	2.40	122
February 6	2.80	327	March 15	2.40	98
February 7	2.68	222	March 17	2.55	120
February 9	2.70	265	March 21	2.60	142
February 11	2.80	333	March 23	2.60	135
February 13	2.80	270	March 25	2.60	130
February 14	2.75	290	March 28	2.50	118
February 15	2.75	272	March 30	2.50	95
February 18	2.65	193	April 1	2.50	86
February 24	2.60	209	April 2	2.50	90
February 27	2.60	184	April 5	2.50	100
March 2	2.50	165	April 7	2.45	97

Discharge measurements of Gila River at the Buttes, Arizona—Continued.

1899—Continued.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
April 10	2.45	78	August 17	2.55	316
April 12	2.40	66	August 19	2.40	207
April 14	2.40	64	August 23	2.25	112
April 17	2.40	59	August 25	2.10	89
April 19	2.35	51	August 29	2.00	71
April 19	2.35	58	August 31	2.00	77
April 21	2.30	50	September 2	2.00	50
April 21	2.30	56	September 4	1.90	42
April 24	2.30	48	September 5	1.90	24
April 24	2.30	48	September 6	1.90	31
April 26	2.30	36	September 7	2.70	267
April 28	2.25	38	September 7	3.90	2,224
May 1	2.25	38	September 8	8.30	10,187
May 3	2.20	29	September 9	4.95	2,923
May 5	2.20	32	September 11	3.50	1,382
May 6	2.15	26	September 12	3.00	734
May 9	2.15	26	September 14	2.07	399
May 11	2.10	24	September 15	2.60	357
May 13	2.10	24	September 16	2.50	288
May 15	2.05	19	September 17	2.40	249
May 17	2.00	12	September 18	2.30	205
May 18	2.00	13	September 19	2.30	202
May 20	2.00	14	September 20	2.20	147
May 23	2.00	8	September 21	2.20	130
May 25	2.00	11	September 22	2.20	126
May 27	1.95	13	September 23	2.10	99
May 29	1.95	7	September 24	2.10	108
May 31	1.90	4	September 25	1.05	93
June 2	2.20	30	September 26	2.00	82
June 5	2.00	12	September 26	2.00	62
June 7	1.90	16	September 27	2.00	77
June 9	1.90	4	September 27	.....	55
June 13	1.80	2	September 28	2.00	68
June 15	1.80	1	September 29	2.00	76
June 19	1.75	1	September 29	2.00	61
June 21	1.75	1	September 30	1.90	54
June 23	1.75	1	October 1	1.90	50
June 26	1.75	2	October 2	1.90	45
June 28	1.75	1	October 3	1.90	40
July 2	1.75	50	October 4	1.90	41
July 4	1.70	25	October 5	1.80	43
July 6	1.70	25	October 5	2.52	330
July 8	1.70	16	October 6	2.10	139
July 10	1.80	2	October 7	2.25	179
July 11	2.75	302	October 8	2.35	219
July 12	2.80	505	October 9	2.30	180
July 13	2.70	263	October 10	2.25	180
July 14	2.50	142	October 11	2.20	96
July 17	2.85	317	October 12	2.20	93
July 18	3.40	1,094	October 13	2.20	110
July 18	2.40	104	October 14	2.10	92
July 19	4.00	1,567	October 16	2.10	96
July 19	4.40	2,095	October 17	2.10	88
July 20	6.60	5,920	October 18	2.10	85
July 20	8.00	8,739	October 19	2.00	71
July 21	5.50	4,339	October 20	2.00	79
August 14	2.75	397	October 21	2.00	76

Measurements were also made of Arthur's ditch, which diverts water one-half mile below the gaging station, of the Florence canal, opposite White's ranch, and of Gila River near the latter place.

The following table shows the measurements made during 1899:

Discharge measurements of Gila River, Arthur's ditch, and Florence canal, Arizona.

1899.

Date.	Stream.	Locality.	Discharge.
			Second-feet.
March 17	Arthur's ditch	One-half mile below station	4.23
March 21	Arthur's ditch	One-half mile below station	4.20
March 21	Gila River	One-half mile below gate of Florence canal.	19.28
March 21	Florence canal	Opposite White's ranch	101.19
April 17	Arthur's ditch	One-half mile below Butte station.	2.15
April 17	Gila River	Below head gate, opposite White's house.	13.43
April 17	Florence canal	At White's ranch, opposite house.	42.61
May 6	Arthur's ditch	On Gila River	3.48
May 6	Gila River	Below Florence canal	8.51
May 6	Florence canal	At White's ranch	10.76
May 18	Gila River	At head of Arthur's ditch at the Buttes.	2.70
May 18	Gila River	Below Florence canal	2.27
May 18	Gila River	Opposite White's ranch	2.94

Daily gage height, in feet, of Gila River at the Buttes, Arizona, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	2.80	2.69	2.50	2.50	2.25	1.90	1.75	4.00	2.00	1.90
2	2.78	2.73	2.50	.....	2.20	2.20	1.70	4.70	2.00	1.90
3	2.80	2.88	2.50	2.45	2.20	2.10	1.70	5.50	.....	1.90
4	2.73	2.93	2.50	2.50	2.20	.....	1.70	4.50	1.90	1.90
5	2.70	2.91	.....	2.50	2.20	2.00	1.70	4.00	1.87	2.15
6	2.65	2.78	2.50	2.50	2.15	1.95	1.70	3.70	1.95	2.15
7	2.60	2.69	2.50	2.45	.....	1.90	1.70	3.80	3.80	2.25
8	2.63	2.71	2.50	2.45	2.15	1.90	1.70	4.50	3.80	2.37
9	2.68	2.72	2.50	.....	2.15	1.90	.....	3.70	4.85	2.30
10	2.60	2.70	2.50	2.45	2.10	1.85	1.80	3.30	4.30	2.22
11	2.73	2.73	2.40	2.45	2.10	1.80	2.75	3.30	3.35	2.20
12	2.70	2.80	.....	2.40	2.10	1.80	2.80	3.10	3.00	2.20
13	3.30	2.80	2.40	2.40	2.10	1.80	2.70	2.80	2.80	2.20
14	3.15	2.78	2.40	2.40	.....	1.80	2.50	2.80	2.65	2.10
15	3.00	2.75	2.40	2.40	2.05	1.80	2.40	2.70	2.60	2.10
16	3.00	2.70	2.50	.....	2.05	1.75	.....	2.60	2.50	2.10
17	2.95	2.67	2.55	2.40	2.00	1.75	2.70	2.50	2.40	2.10
18	2.93	2.68	2.55	2.40	2.00	.....	3.10	2.50	2.30	2.05
19	2.80	2.65	.....	2.35	2.00	1.75	4.20	2.40	2.30	2.00
20	2.73	2.63	2.60	2.30	2.00	1.75	7.80	2.40	2.20	2.05
21	2.70	.....	2.60	2.30	.....	1.75	5.50	.....	2.20	2.05
22	2.70	2.65	.....	2.30	2.00	1.75	4.50	2.30	2.20	.....
23	2.80	2.60	2.60	.....	2.00	1.75	.....	2.30	2.10	.....
24	2.80	2.60	2.50	2.30	2.00	1.75	4.00	2.20	2.10	.....
25	2.75	2.60	2.60	2.30	2.00	1.75	3.90	2.10	2.05	.....
26	.....	2.60	.....	2.30	2.00	1.75	4.00	2.10	2.00	.....
27	2.75	2.60	2.50	2.30	1.95	1.75	4.00	2.10	2.00	.....
28	2.70	2.50	2.50	2.25	.....	1.75	5.25	2.00	2.00	.....
29	2.75	.....	2.50	2.25	1.95	1.75	.....	2.00	1.97	.....
30	2.70	.....	2.50	.....	1.90	.....	.....	2.00	1.90	.....
31	2.68	.....	2.50	.....	1.90	.....	.....	2.00	.....	.....

Station discontinued October 11.

QUEEN CREEK AT WHITLOW'S RANCH, ARIZONA.

This creek is a tributary of the Gila, and has its source in the Pinal Mountains, 40 miles northeast of Florence, Arizona. A short distance below Whitlow's ranch its waters ordinarily are lost in the sands of the desert, and it is only during protracted floods that the discharge continues southwestward, entering Gila River below the Sacaton Range. This basin was under examination in connection with the investigation of the water supply of Gila River.[1]

The discharge of this creek is intermittent, depending upon sudden and violent floods, which are generally of short duration, usually extending over a period of only one day. In order to obtain an accurate estimate of its flow, it is necessary to have an observer constantly on the ground. The station at Whitlow's was established in February, 1896, and was discontinued in April, 1897. It was resumed November 16, 1898, when the original rod was extended, lowering the zero 3 feet. On the same day a sloping rod, referred to the same datum, was placed 431 feet upstream from the main gage. Measurements can be made from a cable and car. It was impracticable, during 1899, to use a meter at this point, so the observer, during the flood stages, observed both gages at short intervals and took soundings from which a cross section could be computed. The discharges were figured by Kutter's formula from these measurements of soundings, and from the slope as determined by the observations of heights on the two rods. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 293; 1897, Nineteenth Annual Report, Part IV, page 418. The following table shows the dates on which there was a discharge in the creek, together with the number of second-feet.

Discharge measurements of Queen Creek at Whitlow's ranch, Arizona.

1899.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
January 12	2.00	.....	June 26	2.30	10
January 12	3.00	.....	July 9	3.00	81
January 13	2.60	.....	July 10	3.10	148
January 13	2.40	.....	July 13	4.50	884
January 14	2.30	.....	July 13	2.40	3
January 14	2.20	.....	July 16	4.00	529
February 3	3.00	87	July 18	3.50	274
February 3	2.80	57	July 25	2.50	2
February 4	2.70	49	July 26	2.50	2
February 4	2.50	11	July 29	2.60	27
February 5	2.40	8	July 30	7.10	5,515
March.			August 1	4.50	492
April.. Creek dry...	.....	.....	August 2	8.00	4,600
May...			August 2	6.00	1,562
June 2	2.70	62	September 7	7.50	.....
June 2	2.30	16	September 8	7.00	.....
June 25	5.00	1,171			

[1] Storage of water on Gila River, Arizona, by J. B. Lippincott: Water-Supply and Irrigation Paper No. 33.

SALT RIVER AT MCDOWELL, ARIZONA.

This river is the principal tributary of Gila River, and rises in Graham County, Arizona, its headwater tributaries adjoining those of San Francisco River. A large portion of its course is through the mountainous district of the White Mountain Indian Reservation. Irrigation is practiced to a small extent in what is known as Tonto Valley, but shortly after Tonto Creek joins it the river enters a canyon again and continues in it until a short distance above the mouth of Verde River. At this point the river reappears from its canyon, and its course is thence across the Plains district until it enters Gila River at the northwest corner of Gila River Indian Reservation. From the mouth of Verde River down to Gila River a number of large canals divert the water of Salt River and serve the extensively irrigated lands in the vicinity of Phœnix on the north side and Mesa on the south side of the river. During ordinary seasons all of the water of Salt River is diverted, and at the present time there is a shortage in the summer months. The gaging station, established April 20, 1897, is located one-half mile above the mouth of the Verde and 30 miles northeast of Phœnix. The gage consists of a 2 by 6 inch scantling bolted to rocks on the south side of the river about 300 feet above the cable. The bench mark is a nail in a palo verde tree about 75 feet west of the north cable anchorage and is 17.33 feet above gage zero. The bed of the river is sandy and shifting, and it is necessary to make a large number of measurements in order to obtain an accurate estimate of the discharge. The results of measurements may be found as follows: 1897, Nineteenth Annual Report, Part IV, page 420; 1898, Twentieth Annual Report, Part IV, page 406. The following discharge measurements were made by W. A. Farish during 1899:

Discharge measurements of Salt River at McDowell, Arizona.

1899.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
January 15	11.40	530	July 16	10.35	204
January 22	11.05	367	August 22	10.55	244
February 12	11.20	390	September 4	10.20	144
February 28	11.20	426	September 10	11.50	716
March 12	11.20	519	October 8	10.40	178
March 31	11.30	602	October 15	11.90	496
April 29	10.85	451	November 30	11.00	226
April 30	10.89	475	December 1	10.96	331
June 29	10.10	173			

A series of measurements of canals diverting water from Salt River in the vicinity of Phœnix were made by Cyrus C. Babb from June 12 to 5, inclusive, in order to determine the amount of return water to the river through seepage. A similar series of measurements were made

in June, 1896. A discussion of these two sets of seepage measurements will be made in the Twenty-first Annual Report.

Miscellaneous discharge measurements in Salt River Valley, Arizona.

1899.

Date.	Stream.	Locality.	Discharge.
			Second-feet.
June 12	Salt River	Gaging station	197.0
June 12	Verde River	Gaging station	140.0
June 13	Arizona canal	Below waste gate	185.0
June 13	Arizona waste	At river	88.0
June 13	Salt River	Opposite Arizona waste gate.	18.7
June 13	Highland canal	Opposite Arizona waste gate.	31.7
June 13	Mesa Consolidated	Below waste gate	67.7
June 13	Small flume	Mesa waste gate	1.8
June 13	Mesa Consolidated waste.	Near gate	15.3
June 13	Salt River	Opposite Mesa Consolidated waste gate.	5.8
June 13	Tempe canal	Ford near head	70.6
June 13	Salt River	Opposite Tempe canal head.	0.0
June 13	Salt River	Railroad bridge	59.8
June 15	Salt River	South of Phœnix	0.0
June 15	St. Johns canal	At head	7.8
June 15	Salt River	Below head of St. Johns canal.	23.9
June 15	Buckeye canal	At head	102.3
June 15	Salt River	Below Buckeye canal	1.0

Daily gage height, in feet, of Salt River at McDowell, Arizona, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	10.80	10.95	11.20	11.30	10.90	10.25	10.10	13.50	10.30	10.30	10.95
2	10.85	11.00	11.15	11.25	10.95	10.35	10.10	17.00	10.35	10.30	10.80
3	10.70	11.10	11.10	11.20	10.80	10.40	10.10	14.30	10.30	10.30	10.80
4	10.70	11.40	11.10	11.15	10.75	10.45	10.05	13.00	10.40	10.40	10.80
5	10.70	11.30	11.15	11.15	10.80	10.45	10.10	12.90	10.40	10.40	10.90
6	10.65	11.25	11.20	11.10	10.75	10.40	10.10	12.70	10.40	10.40	10.90
7	10.70	11.20	11.25	11.20	10.75	10.35	10.05	12.20	10.35	10.40	10.90
8	10.70	11.15	11.25	11.30	10.70	10.35	10.05	11.90	10.30	10.45	10.90
9	10.70	11.10	11.20	11.30	10.65	10.35	10.05	11.10	11.45	10.40	10.90
10	10.70	11.05	11.20	11.30	10.60	10.40	10.10	11.95	12.60	10.40	10.90
11	10.65	11.30	11.20	11.35	10.55	10.30	10.25	11.30	11.65	10.40	10.90
12	11.05	11.20	11.25	11.30	10.50	10.25	10.60	11.40	11.50	10.55	10.90
13	11.90	11.30	11.30	11.35	10.50	10.20	10.50	11.20	11.30	12.70	10.99
14	11.65	11.35	11.25	11.35	10.45	10.20	10.80	11.00	11.00	11.90	11.00
15	11.70	11.30	11.20	11.35	10.50	10.20	10.50	11.00	10.80	11.85	11.00
16	11.30	11.20	11.15	11.35	10.55	10.20	10.40	10.90	10.70	12.30	11.00
17	11.20	11.15	11.10	11.30	10.55	10.20	10.90	11.05	10.60	11.80	11.00
18	11.15	11.15	11.05	11.35	10.55	10.15	10.90	10.95	10.55	11.50	11.00
19	11.15	11.10	11.05	11.35	10.50	10.15	10.80	10.80	10.50	11.30	11.00
20	11.25	11.10	11.10	11.30	10.55	10.10	10.70	10.60	10.45	11.00	11.00
21	11.10	11.10	11.10	11.25	10.55	10.20	11.00	10.60	10.45	11.00	11.00
22	11.10	11.10	11.10	11.25	10.55	10.15	10.75	10.55	10.45	11.00	11.00
23	11.05	11.10	11.10	11.20	10.55	10.20	11.50	10.40	10.40	11.00	11.00
24	11.05	11.15	11.10	11.15	10.60	10.30	11.40	10.40	10.35	11.00	11.00
25	11.00	11.15	11.10	11.15	10.60	10.20	12.50	10.45	10.35	11.00	11.00
26	11.00	11.20	11.10	11.15	10.55	11.10	11.60	10.40	10.35	11.00	11.00
27	10.90	11.20	11.20	11.10	10.50	10.50	11.70	10.40	10.35	10.95	11.00
28	10.90	11.20	11.35	11.10	10.45	10.15	11.60	10.35	10.35	10.95	11.00
29	10.90	.....	11.30	11.05	10.40	10.10	12.70	10.30	10.35	10.95	11.00
30	10.90	.....	11.40	10.90	10.35	10.10	12.80	10.30	10.30	10.90	11.00
31	10.90	.....	11.30	.....	10.30	.....	13.00	10.40	.....	10.90	.....

Station discontinued November 30.

VERDE RIVER AT MCDOWELL, ARIZONA.

This river rises in north-central Arizona and flows in a general southerly direction, entering Salt River 30 miles northeast of Phœnix. A number of large irrigation enterprises have recently been planned and are now in course of construction, designed to divert water from the lower stretch of the river to irrigate lands north of Phœnix. The results of measurements of this river combined with those of Salt River show the amount of water available for the irrigable lands of Phœnix Valley. The dam of the Arizona Canal Company is located on Salt River immediately below the mouth of the Verde. The gaging station of this latter stream is located three-fourths of a mile above its mouth and 30 miles northeast of Phœnix. It was established April 20, 1897. The station is equipped with a cable, car, and tagged wire. The gage consists of a 2 by 4 inch inclined rod fastened to posts driven into the east bank of the river about 400 feet below the gaging cable. The bench mark is on a cat's claw tree about 100 feet southeast from the old gage, on a cottonwood tree, which latter is 60 feet below the cable. The elevation of the bench mark is 27.02 feet above gage datum. The channel of the river is similar to that of Salt River—sandy and liable to change during a slight rise, and a large number of measurements are necessary in order to accurately determine the discharge. The results of measurements may be found as follows: 1897, Nineteenth Annual Report, Part IV, page 420; 1898, Twentieth Annual Report, Part IV, page 407. The following measurements of discharge were made by W. A. Farish during 1899.

Discharge measurements of Verde River at McDowell, Arizona.

1899.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
January 15	7.65	454	July 16	7.50	254
January 22	7.50	356	August 5	8.90	1,213
February 12	7.70	374	August 22	7.35	139
February 28	7.55	324	September 4	7.40	146
March 12	7.55	262	September 10	8.20	481
March 30	7.50	231	October 8	7.50	206
April 29	7.35	191	October 15	9.20	1,670
April 30	7.40	209	November 30	7.80	303
June 29	7.15	127	December 1	7.75	265

Daily gage height, in feet, of Verde River at McDowell, Arizona, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	7.45	7.55	7.55	7.50	7.40	7.15	7.20	8.00	7.35	7.35	7.70
2	7.45	7.55	7.50	7.50	7.40	7.20	7.15	8.30	7.40	7.35	7.70
3	7.45	7.60	7.50	7.50	7.35	7.25	7.15	9.00	7.50	7.35	7.70
4	7.50	7.40	7.55	7.50	7.30	7.20	7.10	9.00	7.40	7.60	7.65
5	7.40	7.60	7.55	7.50	7.30	7.35	7.10	9.50	7.40	7.70	7.70
6	7.40	7.60	7.55	7.50	7.30	7.35	7.10	8.90	7.35	7.50	7.70
7	7.40	7.60	7.55	7.45	7.30	7.35	7.10	8.60	7.40	7.45	7.70
8	7.45	7.55	7.55	7.40	7.30	7.35	7.10	8.30	9.60	7.45	7.70
9	7.40	7.55	7.55	7.45	7.35	7.35	7.10	8.10	9.70	7.45	7.70
10	7.40	7.65	7.55	7.40	7.35	7.30	7.25	8.00	8.30	7.50	7.70
11	7.45	7.70	7.55	7.40	7.25	7.20	7.40	7.80	8.00	7.55	7.70
12	7.40	7.70	7.55	7.40	7.20	7.25	7.70	7.60	7.85	10.50	.....
13	7.80	7.65	7.55	7.40	7.20	7.20	7.60	7.65	7.70	8.60	.....
14	7.75	7.65	7.55	7.40	7.20	7.20	7.80	7.55	7.65	8.50	.....
15	7.70	7.65	7.55	7.40	7.20	7.20	7.60	7.45	7.50	9.30	.....
16	7.45	7.60	7.55	7.35	7.25	7.20	7.70	7.40	7.50	9.25	.....
17	7.40	7.55	7.55	7.30	7.25	4.20	7.50	7.55	7.50	8.60	.....
18	7.45	7.65	7.55	7.35	7.25	7.15	7.40	7.50	7.50	8.20	.....
19	7.45	7.65	7.50	7.35	7.20	7.15	7.60	7.40	7.50	8.20	.....
20	7.60	7.55	7.50	7.35	7.15	7.10	8.40	7.35	7.45	8.00	.....
21	7.60	7.60	7.50	7.35	7.10	7.10	7.60	7.35	7.45	8.00	.....
22	7.50	7.60	7.55	7.35	7.10	7.10	7.45	7.35	7.45	7.90	.....
23	7.45	7.60	7.55	7.35	7.10	7.20	8.50	7.30	7.40	7.85	.....
24	7.50	7.60	7.50	7.35	7.10	7.30	8.25	7.30	7.45	7.80	.....
25	7.55	7.60	7.50	7.35	7.15	7.20	9.05	7.25	7.45	7.80	.....
26	7.50	7.70	7.50	7.35	7.20	7.20	8.60	7.25	7.40	7.80	.....
27	7.40	7.60	7.50	7.40	7.20	7.45	7.70	7.25	7.40	7.80	.....
28	7.55	7.55	7.50	7.35	7.20	7.25	7.75	7.20	7.40	7.80	.....
29	7.45	.....	7.55	7.35	7.20	7.15	8.20	7.20	7.35	7.75	.....
30	7.55	.....	7.55	7.40	7.20	7.15	8.00	7.20	7.40	7.75	.....
31	7.55	.....	7.55	.....	7.20	.....	7.80	7.35	.....	7.70	.....

Station discontinued November 11.

COLORADO RIVER AT YUMA, ARIZONA.

This river drains one of the largest areas in the West. It is formed by the junction of Green and Grand rivers in Utah, and flows in a general southerly direction until it enters the Grand Canyon in northern Arizona, when its general direction is westerly for some distance, and then southerly. It forms the boundary line between Nevada and Arizona, and lower down between California and Arizona. It enters the Gulf of California 70 miles below Yuma. The station is located at the Southern Pacific railroad bridge across the Colorado River at Yuma, Arizona. The gage is fastened to a tall pile about 100 feet east of the north end of the bridge. Low-water readings are taken from a gage placed on the west end of the southern pier. The record here has been kept by the Southern Pacific Railroad Company since April, 1878, and is furnished to this office. No measurements of discharge were made here in 1899.

Daily gage height, in feet, of Colorado River at Yuma, Arizona, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1....	17.75	18.58	19.00	19.00	20.50	23.42	25.67	20.83	18.83	18.00	18.25	18.58
2....	17.92	18.50	19.08	18.83	20.67	23.33	25.58	20.83	18.75	17.92	18.25	18.58
3....	18.00	18.58	19.25	19.00	21.25	23.67	25.58	20.75	18.75	17.83	18.25	18.67
4....	17.92	18.58	19.50	19.00	21.50	23.67	25.50	20.67	18.67	17.75	18.25	18.58
5....	17.83	18.58	19.75	19.00	21.75	23.67	25.33	20.92	18.58	17.75	18.33	18.50
6....	17.75	18.67	19.75	19.00	22.00	23.83	25.00	21.17	18.50	17.75	18.33	18.58
7....	17.75	18.67	19.75	19.00	22.08	23.83	24.75	21.33	18.42	17.75	18.25	18.58
8....	17.92	18.67	19.67	19.00	22.17	24.00	24.67	21.50	18.42	17.67	18.33	18.58
9....	18.08	18.67	19.58	19.83	21.83	24.33	24.50	21.17	18.42	17.50	18.33	18.67
10....	18.08	18.75	19.58	20.17	21.42	24.17	24.33	21.50	18.42	17.50	18.33	18.58
11....	18.00	18.75	19.42	19.83	21.17	24.00	24.33	21.67	18.42	17.50	18.25	18.33
12....	17.83	18.75	19.08	19.75	21.00	23.67	24.08	21.75	18.42	17.50	18.25	18.33
13....	17.75	18.75	19.00	19.58	20.75	23.67	24.00	21.67	18.25	17.33	18.25	18.25
14....	17.67	18.83	19.00	19.50	20.50	23.83	23.83	21.83	18.33	17.25	18.17	18.17
15....	17.75	18.83	19.00	19.50	20.50	24.00	23.75	20.83	18.33	17.17	18.17	18.17
16....	18.00	18.92	19.00	19.50	20.67	24.08	23.33	20.33	18.33	17.00	18.17	18.25
17....	18.42	18.92	19.17	19.58	21.00	24.33	23.17	20.00	18.33	17.00	18.17	18.25
18....	18.58	18.75	19.17	19.50	21.50	24.33	23.00	19.92	18.17	17.00	18.17	18.08
19....	18.67	18.67	19.25	19.50	22.33	24.33	22.83	19.67	18.17	17.08	18.17	18.00
20....	18.67	18.58	19.17	19.50	23.42	24.58	22.58	19.50	18.08	17.08	18.25	17.83
21....	18.67	18.67	19.08	19.42	23.83	24.83	22.42	19.42	18.00	17.08	18.50	17.75
22....	18.67	18.75	19.17	19.42	24.00	25.00	22.17	19.33	17.92	17.17	18.50	17.67
23....	18.75	18.83	19.17	19.50	24.17	25.00	22.00	19.33	17.83	18.67	18.42	17.67
24....	18.67	18.75	19.17	19.58	24.33	25.17	22.00	19.42	17.83	19.17	18.42	17.67
25....	18.67	18.83	19.25	19.67	24.50	25.25	21.67	19.50	17.67	18.92	18.42	17.58
26....	18.67	18.75	19.33	20.33	24.50	25.33	21.83	19.00	17.50	18.67	18.50	17.67
27....	18.67	18.92	19.25	20.92	24.50	25.33	21.75	19.00	18.67	18.50	18.50	17.58
28....	18.58	18.92	19.17	20.92	24.17	25.50	21.50	19.08	18.17	18.25	18.50	17.50
29....	18.42	.....	19.08	20.83	23.83	25.75	21.33	19.00	18.08	18.17	18.50	17.50
30....	18.50	.....	19.00	20.58	23.50	25.67	21.17	18.92	18.00	18.17	18.58	17.33
31....	18.50	.....	19.00	.....	23.33	.....	21.00	18.83	.....	18.25	.....	17.42

NORTH FORK OF HUMBOLDT RIVER AT PEKO, NEVADA.

This tributary of Humboldt River rises in northern Nevada, its headwaters adjoining those of the Owyhee River on the north. Its general course is southerly through a rolling country until it joins the main Humboldt River. The gaging station, established March 25, 1898, by L. H. Taylor, is located at the Southern Pacific railroad bridge about 2 miles west of Peko and a short distance above the mouth of the river. The gage is a vertical timber spiked to the pile support of the railroad bridge. The bench mark is on the stone abutment on the east end of the bridge, on the left bank, and is 12 feet above gage datum. The channel above and below the station is curved, and the current is moderately swift. The bed of the stream is of sand and gravel, shifting somewhat during high stages. The results of measurements for 1898 are shown in the Twentieth Annual Report, Part IV, page 436. The following measurements of discharge were made by L. H. Taylor during 1899:

April 28, gage height, 5 feet; discharge, 732 second-feet.
May 15, gage height, 4.50 feet; discharge, 504 second-feet.
June 26, gage height, 5.70 feet; discharge, 1,053 second-feet.
July 22, gage height, 4 feet; discharge, 331 second-feet.
August 29, gage height, 3.10 feet; discharge, 104 second-feet.
September 30, gage height, 1.75 feet; discharge, 6 second-feet.

Daily gage height, in feet, of North Fork of Humboldt River at Peko, Nevada, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.20	2.40	2.60	4.00	4.50	4.20	4.60	4.20	2.70	1.70	2.30	2.10
2	2.20	2.60	2.60	4.00	4.40	4.00	4.50	4.10	2.70	1.70	2.30	2.00
3	2.40	2.60	2.70	4.00	4.30	4.00	4.50	4.00	2.70	1.70	2.30	2.20
4	2.40	2.60	2.70	4.20	4.20	4.00	4.60	4.00	2.70	1.70	2.30	2.20
5	2.60	2.50	2.80	4.20	4.10	4.10	4.60	4.00	2.80	1.80	2.30	2.30
6	2.70	2.50	2.90	4.30	4.00	4.20	4.50	3.90	2.80	1.80	2.30	2.30
7	2.70	2.60	2.90	4.30	4.00	4.30	4.40	3.70	2.70	1.80	2.30	2.30
8	2.20	2.60	3.00	4.30	3.40	4.40	4.30	3.60	2.60	1.70	2.40	2.30
9	2.20	2.60	3.40	4.80	3.00	4.40	4.20	3.40	2.60	1.70	2.40	2.30
10	2.30	2.70	3.50	4.90	3.00	4.40	4.20	3.20	2.70	1.70	2.40	2.30
11	2.30	2.70	3.60	5.00	3.40	4.20	4.30	3.10	2.80	1.80	2.40	2.30
12	2.40	2.50	3.20	5.00	3.50	4.30	4.20	3.10	2.80	1.80	2.40	2.30
13	2.40	2.50	3.20	5.40	3.40	4.40	4.10	3.00	2.80	1.80	2.40	2.40
14	2.40	2.60	3.30	5.60	4.40	4.50	4.20	3.00	2.70	1.90	2.30	2.40
15	2.70	2.60	3.30	6.30	4.50	4.70	4.10	2.90	2.60	2.00	2.30	2.40
16	2.70	2.60	3.40	6.80	4.60	4.90	4.20	2.80	2.60	2.00	2.20	2.40
17	2.80	2.60	3.40	6.80	4.70	5.00	4.20	2.80	2.60	2.00	2.10	2.20
18	2.80	2.60	3.50	6.70	4.70	5.60	4.00	2.70	2.60	2.00	2.10	2.30
19	2.90	3.30	3.60	6.70	4.80	5.80	4.00	2.70	2.60	2.10	2.10	2.30
20	3.00	3.30	3.60	6.60	4.80	5.90	4.10	3.00	2.50	2.10	2.10	2.30
21	3.00	3.30	3.70	6.50	4.00	6.00	4.00	3.00	2.50	2.10	2.20	2.30
22	2.40	3.40	3.70	6.00	4.10	6.00	4.00	2.90	2.50	2.10	2.20	2.30
23	2.40	3.40	3.80	5.20	4.20	6.10	4.60	2.90	2.40	2.10	2.20	2.30
24	2.50	3.50	3.90	5.20	4.30	6.00	4.60	2.80	2.30	2.10	2.20	2.30
25	2.50	3.50	4.00	5.30	4.30	5.90	4.50	2.80	2.20	2.10	2.30	2.30
26	2.60	2.50	3.60	5.30	4.40	5.60	4.50	2.80	2.00	2.20	2.20	2.30
27	2.60	2.50	3.70	5.20	4.40	5.80	4.40	2.80	1.90	2.20	2.20	2.20
28	2.60	2.50	3.70	5.00	4.00	5.20	4.20	2.90	1.80	2.20	2.20	2.20
29	2.20	.....	3.70	4.70	4.00	4.90	4.20	2.90	1.80	2.20	2.10	2.30
30	2.20	.....	3.80	4.60	4.10	4.70	4.30	2.80	1.80	2.20	2.10	2.30
31	2.40	.....	3.90	.....	4.20	.....	4.30	2.80	.....	2.30	.....	2.30

HUMBOLDT RIVER AT ELKO, NEVADA.

This river rises in the extreme northeastern part of Nevada, and flows in a general westerly and southerly direction, finally entering Humboldt Lake, whence its waters find their way into Humboldt and Carson sinks. The general direction of the mountain ranges of this basin is north and south, crossed at nearly right angles by the main Humboldt River. The tributaries flow in the general direction of the mountain ranges and drain either northward or southward. The basin may be divided into three divisions—the eastern, or headwater division, separated from the middle or Battle Mountain Valley by Palisade Canyon; the central and western divisions, separated by Hot Springs Range on the north and by Battle Mountain and Sonoma ranges on the south. There is a large body of agricultural land in the basin of Humboldt River which at the present time is not wholly reclaimed. During low stages the river is wholly diverted. For the future development of the country recourse must be had to the construction of reservoirs for storage purposes. The station at Elko, established June 17, 1895, by L. H. Taylor, is located at the highway bridge 1 mile southwest of the town. The gage is inclined, fastened to iron bolts driven into the solid rock, and is placed on the left bank immediately below the bridge. The bench mark is on the southwest corner of the cofferdam surrounding the stone pier of the bridge 80 feet north of the gage, and is at an elevation of 7.50 feet above gage datum. The right bank is quite low, the left is high and rocky. The

bed of the stream is of gravel and sand, with a slight tendency to change its channel during flood stages. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 300; 1897, Nineteenth Annual Report, Part IV, page 425; 1898, Twentieth Annual Report, Part IV, page 437. The following measurements of discharge were made by L. H. Taylor during 1899:

Discharge measurements of Humboldt River at Elko, Nevada.

1899.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
April 27	6.40	1,421	July 2	7.10	1,817
May 10	5.40	984	July 22	4.50	630
June 10	5.90	1,245	August 28	2.80	144
June 26	7.80	2,260	September 29	2.10	31

Daily gage height, in feet, of Humboldt River at Elko, Nevada, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.90	2.30	2.75	4.35	6.40	5.70	7.20	3.70	2.80	2.15	3.50	2.80
2	1.90	2.30	2.80	4.25	6.10	5.80	7.15	3.60	2.80	2.15	3.50	2.75
3	1.90	2.35	2.85	4.20	5.80	5.80	7.00	3.40	2.80	2.15	3.55	2.60
4	1.90	2.35	2.85	4.20	5.60	5.80	6.90	3.30	2.80	2.15	3.55	2.59
5	1.90	2.35	2.90	4.20	5.60	5.80	6.90	3.20	2.80	2.15	3.55	2.58
6	1.90	2.35	3.00	4.20	5.60	5.80	6.75	3.20	2.80	2.15	3.56	2.57
7	1.90	2.35	3.00	4.20	5.80	5.90	6.60	3.10	2.80	2.15	3.55	2.58
8	1.90	2.35	3.05	4.20	5.70	5.90	6.40	3.10	2.80	2.20	3.55	2.59
9	1.90	2.30	3.05	4.35	5.55	5.90	6.20	3.10	2.80	2.20	3.55	2.60
10	1.90	2.30	3.05	4.40	5.40	5.95	6.05	3.10	2.70	2.20	3.60	2.60
11	1.95	2.30	3.05	4.90	5.20	6.00	5.80	2.90	2.70	2.20	3.60	2.60
12	1.95	2.30	3.05	5.15	5.20	6.20	5.65	2.90	2.70	2.40	3.60	2.60
13	1.95	2.35	3.05	5.50	5.20	6.30	5.50	2.70	2.70	2.80	3.60	2.65
14	1.95	2.35	3.10	6.20	5.35	6.40	5.30	2.60	2.70	2.90	3.62	2.65
15	1.90	2.35	3.15	6.90	5.65	6.60	5.25	2.50	2.70	3.15	3.62	2.60
16	1.95	2.35	3.15	7.30	5.90	7.00	5.20	2.50	2.70	3.15	3.65	2.60
17	2.00	2.40	3.10	7.20	6.30	7.25	5.10	2.60	2.60	3.20	3.65	2.58
18	2.00	2.40	3.05	7.15	6.50	7.20	4.90	2.60	2.60	3.20	3.65	2.55
19	2.00	2.50	3.15	7.15	6.75	7.30	4.75	2.70	2.60	3.25	3.65	2.54
20	2.05	2.55	3.20	7.15	6.80	7.30	4.50	2.90	2.60	3.30	3.65	2.54
21	2.05	2.60	3.20	7.10	6.65	7.50	4.50	2.80	2.60	3.30	3.66	2.53
22	2.15	2.60	3.30	7.10	6.40	7.75	4.50	2.80	2.60	3.30	3.67	2.52
23	2.15	2.70	3.40	6.80	6.10	8.00	4.50	2.80	2.50	3.35	3.67	2.50
24	2.20	2.70	3.70	6.60	5.85	8.00	4.50	2.80	2.50	3.35	3.67	2.50
25	2.25	2.70	3.75	6.50	5.40	8.00	4.35	2.80	2.40	3.40	3.67	2.48
26	2.30	2.75	4.60	6.50	5.10	7.80	4.30	2.80	2.30	3.40	3.60	2.45
27	2.35	2.75	4.55	6.40	5.10	7.70	4.20	2.80	2.20	3.45	3.40	2.43
28	2.35	2.75	4.45	6.40	5.10	7.60	4.15	2.80	2.10	3.45	3.15	2.40
29	2.30	.....	4.40	6.40	5.45	7.50	4.00	2.80	2.10	3.45	3.00	2.39
30	2.30	.....	4.35	6.40	5.50	7.35	3.90	2.80	2.10	3.45	2.90	2.36
31	2.30	.....	4.35	.....	5.60	.....	3.80	2.80	.....	3.45	.....	2.35

SOUTH FORK OF HUMBOLDT RIVER AT MASON'S RANCH, NEVADA.

This tributary rises in Eureka and White Pine counties, and takes a nearly due north course, entering the main Humboldt River 10 miles below Elko. The little irrigation practiced in the basin is almost exclusively for forage plants. The measurements of discharge show the amount of water available for storage. There is a good site for a reservoir a short distance above the station. The station, established August 29, 1896, by L. H. Taylor, is located 10 miles southwest of

the town of Elko and about 6 miles above the junction of the South Fork with the main stream. The gage is inclined and spiked to posts driven firmly into the right bank. The bench mark is the top of a 2 by 4 inch post, 2½ feet long, driven flush with the ground 10 feet north of the gage, and is at an elevation of 7.50 feet above gage datum. The measurements are made from a cable and suspended car, at a point 1 mile above the gage, the latter being placed near the farm of the observer, for his convenience. At the point of measurement the banks are high, and the channel is straight for some distance above and below the station. The bed of the stream is of rock and gravel and quite stable. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 311; 1897, Nineteenth Annual Report, Part IV, page 430; 1898, Twentieth Annual Report, Part IV, page 440. The following discharge measurements were made by L. H. Taylor during 1899:

April 27, gage height, 2.50 feet; discharge, 404 second-feet.
May 10, gage height, 1.80 feet; discharge, 227 second-feet.
June 10, gage height, 3.30 feet; discharge, 658 second-feet.
June 25, gage height, 4.80 feet; discharge, 1,122 second-feet.
July 2, gage height, 4.15 feet; discharge, 910 second-feet.
August 28, gage height, 0.75 foot; discharge, 42 second-feet.
September 29, gage height, 0.55 foot; discharge, 20 second-feet.

Daily gage height, in feet, of South Fork of Humboldt River at Mason's ranch, Nevada, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.00	1.30	1.20	1.85	2.00	2.30	4.25	1.75	0.60	0.60	0.80	0.90
2	1.00	1.30	1.30	1.85	1.90	2.35	4.25	1.75	.55	.60	.80	.90
3	1.00	1.30	1.30	1.85	1.85	2.45	4.10	1.70	.55	.60	.80	.90
4	1.00	1.30	1.25	1.80	1.80	2.35	3.90	1.60	.55	.65	.80	.90
5	1.00	1.20	1.20	1.90	1.75	2.45	3.70	1.60	.55	.65	.80	.90
6	1.00	1.20	1.20	1.95	1.70	2.65	3.70	1.60	.55	.65	.80	.90
7	1.00	1.25	1.20	2.15	1.65	2.90	3.70	1.60	.55	.65	.80	.90
8	1.10	1.25	1.45	2.40	1.65	3.00	3.50	1.60	.55	.65	.80	.90
9	1.10	1.35	1.55	2.30	1.65	3.10	3.40	1.50	.55	.70	.80	.90
10	1.10	1.50	1.40	2.80	1.75	3.30	3.30	1.45	.55	.70	.80	.90
11	1.10	1.80	1.30	2.80	2.00	3.65	3.25	1.40	.55	.70	.80	.90
12	1.10	1.65	1.25	2.90	2.15	3.80	3.10	1.40	.55	.70	.80	.85
13	1.20	1.65	1.25	2.90	2.35	4.60	3.00	1.30	.55	.70	.80	.85
14	1.20	1.40	1.20	2.90	2.50	4.60	3.00	1.25	.55	.70	.85	.85
15	1.20	1.50	1.20	2.90	2.65	4.40	2.90	1.20	.55	.70	.85	.85
16	1.20	2.10	1.45	2.90	2.65	4.30	2.80	1.15	.55	.70	.85	.85
17	1.20	2.15	1.45	2.90	2.55	4.40	2.70	1.10	.55	.70	.85	.70
18	1.20	2.20	1.45	2.90	2.40	4.80	2.60	1.10	.55	.70	.90	.70
19	1.20	2.10	1.50	2.70	2.30	5.20	2.60	1.10	.55	.70	.90	.70
20	1.20	2.10	1.50	2.50	2.20	5.40	2.50	1.00	.55	.70	.90	.70
21	1.20	1.80	1.50	2.45	2.20	5.65	2.50	1.00	.55	.70	.90	.70
22	1.30	1.50	1.50	2.45	2.10	5.30	2.50	.95	.55	.75	.90	.70
23	1.30	1.50	1.50	2.60	2.00	5.00	2.30	.90	.55	.80	.90	.70
24	1.30	1.40	2.15	2.60	1.95	4.70	2.10	.90	.55	.80	.90	.75
25	1.30	1.40	2.70	2.60	1.90	4.60	2.10	.85	.55	.80	.90	.80
26	1.30	1.15	2.70	2.50	2.00	4.50	2.10	.80	.55	.85	.90	.80
27	1.30	1.25	2.30	2.45	2.20	4.40	2.00	.75	.55	.85	.90	.80
28	1.30	1.20	2.10	2.35	2.20	4.20	2.00	.70	.60	.85	.90	.90
29	1.30	.....	2.10	2.10	2.15	4.20	2.00	.70	.60	.85	.90	.90
30	1.30	.....	1.95	2.10	2.20	4.30	1.90	.65	.60	.85	.90	.90
31	1.30	.....	1.85	.....	2.20	.....	1.80	.60	.....	.85	.....	.90

HUMBOLDT RIVER AT GOLCONDA, NEVADA.

The gaging station at Golconda is located near the great northern bend of Humboldt River and below the central valley. It is about 15 miles above the mouth of Little Humboldt River. The station was established by L. H. Taylor October 24, 1894, and has been maintained continuously since that time. It is located 1¼ miles north of the town. The gage is vertical and spiked to posts driven into the left bank of the river. Bench mark No. 1 is the top of a 2 by 4 inch post driven flush with the ground surface 20 feet from the gage, and is at an elevation of 10.55 feet above gage datum. Bench mark No. 2 is the top of a large spike driven into a post which is set firmly into the ground about 15 feet from the gage, and is 13.70 feet above gage datum. Measurements are made from cable and suspended car. The banks are moderately high, but liable to overflow at extreme high stages. The bed of the stream is of gravel and sand, somewhat shifting. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 306; 1897, Nineteenth Annual Report, Part IV, page 427; 1898, Twentieth Annual Report, Part IV, page 438. The following measurements were made by L. H. Taylor in 1899:

April 29, gage height, 8.10 feet; discharge, 2,157 second-feet.
May 26, gage height, 7 feet; discharge, 1,440 second-feet.
June 30, gage height, 7.60 feet; discharge, 1,767 second-feet.
July 30, gage height, 6.30 feet; discharge, 1,058 second-feet.
August 25, gage height, 3.50 feet; discharge, 316 second-feet.
September 28, gage height, 1.05 feet; discharge, 37 second-feet.

Daily gage height, in feet, of Humboldt River at Golconda, Nevada, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.70	2.60	3.60	5.70	8.10	7.00	7.70	6.10	2.20	1.00	1.30	2.00
2	.80	2.70	3.50	5.80	8.10	6.80	7.70	6.00	1.90	1.00	1.35	2.00
3	.80	2.80	3.50	5.90	8.20	7.00	7.80	5.90	1.70	1.00	1.40	2.00
4	.80	2.80	3.50	6.00	8.30	7.10	8.00	5.80	1.60	.95	1.50	2.05
5	.80	2.80	3.50	6.10	8.20	7.05	8.00	5.50	1.50	.95	1.55	2.05
6	.80	2.90	3.50	6.20	8.20	7.00	8.00	5.40	1.45	.95	1.60	2.05
7	.80	2.90	3.50	6.30	8.20	7.00	8.00	5.30	1.40	.95	1.60	2.05
8	.80	2.90	3.50	6.40	8.20	6.90	8.10	5.20	1.40	.90	1.65	2.05
9	.80	2.90	3.60	6.40	8.20	6.90	8.10	5.00	1.40	.90	1.65	2.10
10	.80	2.90	3.60	6.50	8.10	6.80	8.10	5.00	1.35	.90	1.70	2.10
11	.80	2.90	3.60	6.60	8.00	6.70	7.90	4.90	1.35	.90	1.70	2.10
12	.80	2.90	3.60	6.70	8.00	6.70	7.80	4.80	1.30	.90	1.70	2.10
13	.80	3.10	3.60	6.70	8.00	6.60	7.70	4.80	1.30	.90	1.75	2.10
14	.80	3.50	3.60	6.70	8.00	6.60	7.60	4.70	1.30	.90	1.75	2.15
15	.80	3.60	3.60	6.70	8.00	6.50	7.60	4.60	1.25	.90	1.80	2.15
16	.90	3.80	3.60	6.80	7.90	6.50	7.50	4.50	1.25	.90	1.80	2.15
17	1.30	3.80	3.60	6.80	7.80	6.60	7.50	4.50	1.20	.95	1.85	2.15
18	1.20	3.80	3.60	6.90	7.70	6.70	7.40	4.30	1.20	.95	1.85	2.15
19	1.40	3.90	3.60	6.90	7.60	6.80	7.40	4.30	1.15	1.00	1.85	2.15
20	1.50	3.90	3.60	7.50	7.50	6.90	7.30	4.20	1.15	1.00	1.90	2.15
21	1.50	3.90	4.00	7.50	7.50	7.10	7.30	4.10	1.10	1.00	1.90	2.20
22	1.50	3.90	4.40	7.50	7.40	7.30	7.00	4.00	1.10	1.05	1.90	2.20
23	1.70	3.80	4.50	7.50	7.20	7.40	7.00	3.80	1.10	1.05	1.90	2.20
24	1.80	3.90	4.50	7.60	7.20	7.50	6.90	3.60	1.05	1.10	1.95	2.20
25	2.10	3.70	4.70	7.70	7.00	7.50	6.80	3.50	1.05	1.10	1.95	2.15
26	2.50	3.70	4.70	7.80	7.00	7.70	6.80	3.30	1.05	1.15	1.95	2.15
27	2.60	3.70	5.10	7.80	7.10	7.80	6.60	3.10	1.05	1.15	1.95	2.10
28	2.60	3.70	5.40	7.90	7.20	7.70	6.50	2.90	1.05	1.20	2.00	2.10
29	2.60	.....	5.70	8.10	7.20	7.60	6.40	2.70	1.05	1.20	2.00	2.15
30	2.60	.....	5.70	8.10	7.30	7.60	6.30	2.60	1.05	1.25	2.00	2.15
31	2.60	.....	5.70	.....	7.40	.....	6.20	2.40	.....	1.25	.....	2.20

HUMBOLDT RIVER AT OREANA, NEVADA.

On the lower reaches of this river measurements have been made for a number of years at Oreana, and the results show the amount of water available for storage at the possible reservoir sites in the vicinity of Humboldt Station, and also for the six canal systems now in operation below Oreana. The station, established by L. H. Taylor January 27, 1896, is located 1½ miles above the old Oreana highway bridge, 12 miles northeast of Lovelock, and above all the canals diverting water in the vicinity of that town. The gage rod is an inclined 2 by 4 inch pine timber, spiked to posts driven well into the bank of the river. The bench mark is a 10 by 10 inch post near the left bank of the stream, about 40 feet from the gage, and is at an elevation of 10 feet above gage datum. The station is provided with a cable and car. The river banks are high and not liable to overflow. The bed of the river is sandy and shifting. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 307; 1897, Nineteenth Annual Report, Part IV, page 428; 1898, Twentieth Annual Report, Part IV, page 439. The following measurements of discharge were made by L. H. Taylor during 1899:

June 29, gage height, 4.50 feet; discharge, 1,951 second-feet.
August 2, gage height, 3.60 feet; discharge, 1,214 second-feet.
August 30, gage height, 1.80 feet; discharge, 241 second-feet.
September 26, gage height, 1.20 feet; discharge, 100 second-feet.
October 27, gage height, 0.90 foot; discharge, 60 second-feet.

Daily gage height, in feet, of Humboldt River at Oreana, Nevada, for 1899.

Day.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	4.50	3.70	1.80	1.10	0.90	1.20
2	.....	4.50	3.60	1.70	1.10	.90	1.20
3	.....	4.55	3.50	1.70	1.05	.90	1.20
4	.....	4.55	3.30	1.70	1.05	.90	1.30
5	.....	4.55	3.20	1.60	1.05	.90	1.30
6	.....	4.60	3.20	1.60	1.00	.90	1.30
7	.....	4.60	3.10	1.60	1.00	.90	1.30
8	.....	4.60	3.00	1.50	1.00	1.00	1.30
9	.....	4.65	3.00	1.50	1.00	1.00	1.30
10	.....	4.70	2.90	1.50	.95	1.10	1.40
11	.....	4.70	2.90	1.50	.95	1.10	1.40
12	.....	4.70	2.80	1.50	.95	1.20	1.40
13	.....	4.80	2.80	1.45	.95	1.20	1.40
14	.....	4.80	2.70	1.45	.90	1.20	1.40
15	.....	4.90	2.60	1.40	.90	1.20	1.50
16	.....	4.90	2.60	1.40	.90	1.20	1.50
17	.....	4.90	2.50	1.40	.90	1.20	1.50
18	.....	5.00	2.50	1.35	.90	1.20	1.60
19	.....	5.00	2.40	1.35	.90	1.20	2.00
20	.....	5.00	2.40	1.30	.90	1.20	2.00
21	.....	5.00	2.30	1.30	.90	1.20	2.00
22	.....	4.90	2.20	1.30	.90	1.20	2.00
23	.....	4.70	2.10	1.25	.90	1.20	2.00
24	.....	4.55	2.10	1.25	.90	1.20	2.60
25	.....	4.30	2.00	1.20	.90	1.20	2.60
26	.....	4.10	2.00	1.20	.90	1.20	2.60
27	.....	3.95	2.00	1.20	.90	1.20	2.40
28	.....	3.85	1.90	1.15	.90	1.20	2.40
29	4.50	3.80	1.90	1.15	.90	1.20	2.40
30	4.50	3.90	1.80	1.10	.90	1.20	2.40
31	.....	3.80	1.80	.....	.90	.....	2.40

TRUCKEE RIVER AT NEVADA–CALIFORNIA STATE LINE.

This river has its source on the slopes of the Sierra Nevada in eastern California and flows northward, entering Lake Tahoe. This lake is at an elevation of 6,225 feet, and is the largest body of fresh water in the United States at this considerable altitude. The area of the lake itself is 193 square miles. As the State line between Nevada and California passes through the lake, a portion of it is in each State. The outlet of the lake is at Tahoe, California, and Truckee River from this point has a general northward course, receiving a number of important tributaries which contribute to its flow. There are a number of lakes at the head waters of the branch streams, which have been surveyed and recommended as reservoir sites. The drainage area is mapped on the Pyramid Peak, Truckee, Carson, and Markleeville atlas sheets of the United States Geological Survey. The basin is now partially included in the Lake Tahoe Forest Reserve, set apart by Executive proclamation of April 13, 1899. September 7, 1899, a station was established on this river by L. H. Taylor, at the State line, 17 miles west of Reno, Nevada. The gage is vertical, driven into the bed of the river and wired to a granite bowlder. The bench mark is the top of the rock to which the rod is fastened, and is at an elevation of 10 feet above gage datum. The channel is straight for a short distance above and below the station. The banks are not liable to overflow. The bed of the river is of gravel and cobbles and quite stable. One measurement of discharge was made by L. H. Taylor on September 7, 1899, when at a gage height of 2 feet a discharge of 303 second-feet was found.

Daily gage height, in feet, of Truckee River at Nevada–California State line, for 1899.

Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.
1	.....	1.90	2.10	1.90	17	2.00	1.90	2.70	1.90
2	.....	1.90	2.10	1.90	18	1.90	1.90	2.50	1.90
3	.....	1.90	2.00	1.90	19	1.90	1.90	2.50	1.90
4	.....	1.90	2.00	1.90	20	1.90	2.40	2.30	1.90
5	.....	1.90	2.00	1.90	21	1.90	2.50	2.20	1.90
6	.....	1.90	2.60	1.80	22	1.90	2.70	2.10	1.90
7	2.00	1.90	2.80	1.80	23	1.90	2.50	2.00	1.90
8	2.00	1.90	3.20	1.80	24	2.00	2.40	2.00	1.90
9	1.90	1.90	3.80	1.90	25	1.90	2.80	2.00	1.90
10	1.90	1.90	4.00	1.90	26	1.90	2.20	2.00	1.90
11	1.90	1.90	4.20	1.90	27	1.90	2.10	2.00	1.90
12	1.90	2.00	3.50	1.90	28	1.90	2.00	2.00	1.90
13	1.90	2.00	3.00	2.00	29	1.90	2.00	1.90	1.90
14	1.90	2.00	2.70	2.00	30	1.90	2.10	1.90	1.90
15	1.90	1.90	2.90	2.00	31	.....	2.10	.....	1.90
16	2.10	1.90	2.70	1.90					

TRUCKEE RIVER AT VISTA, NEVADA.

On the lower courses of this river are located considerable stretches of irrigable land, which, however, have not yet been developed to their fullest extent. The drainage basin is peculiar in that its moun-

tainous collecting area is located in the State of California, while the lands which can be irrigated are situated in Nevada. This may lead in the future to certain legal difficulties, but not to the extent that it would if there were agricultural lands in both States. Truckee River after entering Nevada flows in a general easterly and then northerly direction, emptying into Pyramid Lake. The drainage area is mapped on the following atlas sheets of the United States Geological Survey: Pyramid Peak, Truckee, Markleeville, Carson, Reno, and Wadsworth. The station at Vista, Nevada, was established August 18, 1899, by L. H. Taylor, and is located 7 miles east of Reno, near the point where measurements were made in 1890, 1891, and 1892, the results of which are shown in the Thirteenth Annual Report, Part III, page 95. The rod is spiked to posts driven into the bed of the river. The bench mark is on a bluff of rocks 500 feet east of the gage, and is at an elevation of 17.50 feet above gage datum. Both banks are high and not liable to overflow. The bed is rocky and not subject to change. Three ditches diverting water from Truckee River above Reno were measured by L. H. Taylor on September 4, 1899, with the following results: Highland ditch, 6 miles above Reno, 4 miles below the head of ditch, discharge 16.7 second-feet; Maybury ditch at flume across Hunter Creek, 1 mile below head of ditch and 5 miles west of Reno, discharge 47 second-feet; Orr ditch at stone culvert under Southern Pacific Railroad, 1 mile below head of ditch, discharge 42 second-feet. Two measurements of discharge were made by L. H. Taylor during 1899, as follows: The first, on September 5, at a gage height of 2 feet, showed a discharge of 105 second-feet; the second measurement, on October 28, at a gage height of 2.75 feet, gave a discharge of 477 second-feet.

Daily gage height, in feet, of Truckee River at Vista, Nevada, for 1899.

Day.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	1.95	2.10	2.70	2.55	17	.....	2.15	2.60	3.50	2.90
2	.....	1.90	2.15	2.70	2.50	18	2.00	2.10	2.60	3.20	2.80
3	.....	2.00	2.15	2.60	2.60	19	2.10	2.10	2.50	3.10	2.80
4	.....	2.00	2.15	2.60	2.65	20	2.20	2.10	3.50	2.90	2.80
5	.....	2.00	2.15	2.60	2.60	21	2.00	2.10	3.90	2.80	2.60
6	.....	2.00	2.15	2.60	2.60	22	2.10	2.10	3.60	2.70	2.60
7	.....	2.00	2.15	2.70	2.60	23	2.00	2.10	3.00	2.60	2.60
8	.....	2.00	2.15	2.70	2.50	24	2.10	2.10	2.90	2.70	2.65
9	.....	2.05	2.15	2.80	2.50	25	2.05	2.10	2.80	2.70	2.65
10	.....	2.10	2.15	2.80	2.60	26	2.00	2.10	2.80	2.70	2.65
11	.....	2.05	2.15	3.00	2.60	27	2.00	2.10	2.80	2.70	2.70
12	.....	2.10	2.30	4.00	3.10	28	1.90	2.10	2.80	2.60	2.90
13	.....	2.10	2.50	3.70	2.90	29	1.95	2.10	2.80	2.55	3.20
14	.....	2.05	2.60	3.20	2.80	30	1.95	2.10	2.80	2.55	3.00
15	.....	2.15	2.50	3.20	3.25	31	1.90	.....	2.70	.....	3.00
16	.....	2.20	2.50	3.60	3.10						

BEAR RIVER AT BATTLECREEK, IDAHO.

This river has its source on the northern slope of the Uinta Mountains, in the northeastern part of Utah. Its general course is northerly, entering Wyoming at the southwestern corner of the State. It

shortly afterwards swings back into Utah again and then reenters Wyoming. After its junction with Smiths Fork it swings to the westward again, leaves Wyoming for the last time, and enters Idaho. Twenty-eight miles below the outlet of Bear Lake the river makes a sudden bend to the south, and its course is thence southerly, reentering Utah and finally discharging its waters into Great Salt Lake. There are a number of reservoir sites in its upper basin, which have not, however, been examined in detail. Considerable irrigation is practiced, commencing at a point where the river first enters Wyoming and thence extending downstream to the outlet of Bear Lake. At the present time all of the low-water flow is thus utilized, resulting in a scarcity during the latter part of the irrigation season. Bear Lake acts as a regulator to the discharge of the portion of the river below it. The lake itself is one of the finest natural reservoir sites in the country and could be utilized with small expense. That it has not been utilized before this is due to the abundant water supply of the lands below. The agricultural lands in Idaho adjacent to this river are of small extent, and at the present time little water is diverted; nor does it receive a large additional supply in this State, except in times of flood discharges. The gaging station at Battle-creek was established on October 11, 1889, and is located about 10 miles north of the Utah-Idaho boundary line. The measurements show the amount of water of this river available for irrigation purposes in Cache Valley, Utah. The gage consisted of a vertical board nailed to a pile. This was carried away June 30, 1899, but was replaced on August 4 by a wire and weight, readings being made on a horizontal scale. The bench mark for the old gage is described in Water-Supply Paper No. 16, page 157. It was a nail in the southeast corner of a house near the gage, about 1.5 feet from the ground and 10.95 feet above gage datum. The bench mark for the present gage is a mark of black paint on the top of a log projecting from the southeast corner of the observer's house, about 2 feet above the surface of the ground and 11.118 feet above gage datum. The station is equipped with a cable and car. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 315; 1897, Nineteenth Annual Report, Part IV, page 432; 1898, Twentieth Annual Report, Part IV, page 459. The following measurements of discharge were made by J. S. Baker and G. L. Swendsen during 1899:

March 28, gage height, 1.75 feet; discharge, 773 second-feet.
May 8, gage height, 3.25 feet; discharge, 2,376 second-feet.
July 3, gage out; discharge, 4,781 second-feet.
August 4, gage height, 3.01 feet; discharge, 1,732 second-feet.
December 4, gage height, 2.21 feet; discharge, 1,312 second-feet.

Daily gage height, in feet, of Bear River at Battlecreek, Idaho, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.60	1.60	1.50	1.90	3.50	4.10	.....	2.10	2.00	2.20	2.20
2	1.60	1.60	1.50	1.90	3.50	4.10	.....	2.10	2.00	2.20	2.20
3	1.60	1.60	1.50	2.00	3.40	4.10	.....	.....	2.00	2.20	2.20
4	1.60	1.60	1.50	2.00	3.40	4.10	3.10	.....	2.00	2.20	2.20
5	1.60	1.60	1.50	2.15	3.40	4.10	3.00	.....	2.00	2.20	2.10
6	1.60	1.60	1.50	2.15	3.30	4.15	3.00	.....	2.00	2.20	2.10
7	1.60	1.60	1.50	2.15	3.20	4.20	2.90	.....	2.00	2.20	2.00
8	1.60	1.60	1.50	2.25	3.20	4.20	2.90	.....	2.00	2.20	1.90
9	1.60	1.60	1.50	2.60	3.30	4.20	2.90	.....	2.00	2.20	1.90
10	1.60	1.60	1.50	2.85	3.40	4.25	2.90	2.10	2.00	2.20	1.80
11	1.60	1.60	1.50	2.90	3.40	4.30	2.90	2.10	2.00	2.20	1.70
12	1.60	1.60	1.50	3.10	3.50	4.30	2.90	2.10	2.00	2.40	2.30
13	1.60	1.60	1.50	3.45	3.60	4.30	2.90	2.10	2.15	2.40	2.20
14	1.60	1.60	1.50	3.55	3.60	4.40	2.90	2.10	2.20	2.40	2.20
15	1.60	1.60	1.50	3.60	3.60	4.40	2.80	2.10	2.20	2.40	2.10
16	1.60	1.60	1.50	3.50	3.60	4.40	2.80	2.10	2.20	2.40	2.10
17	1.60	1.60	1.50	3.50	3.60	4.40	2.70	2.10	2.20	2.40	2.10
18	1.60	1.50	1.50	3.40	3.70	4.40	2.70	2.10	2.20	2.40	2.00
19	1.60	1.50	1.50	3.45	3.80	4.40	2.60	2.10	2.20	2.40	2.00
20	1.60	1.50	1.60	3.30	3.80	4.40	2.60	2.10	2.20	2.40	2.00
21	1.60	1.50	1.60	3.30	3.80	4.40	2.50	2.10	2.20	2.30	1.90
22	1.60	1.50	1.60	3.30	3.80	4.50	2.50	2.10	2.30	2.30	1.90
23	1.60	1.50	1.60	3.40	3.80	4.50	2.40	2.10	2.30	2.30	1.90
24	1.60	1.50	1.65	3.40	3.80	4.50	2.30	2.00	2.30	2.30	1.90
25	1.60	1.50	1.90	3.40	3.90	4.60	2.30	2.00	2.30	2.30	1.90
26	1.60	1.50	1.90	3.45	3.90	4.60	2.30	2.00	2.30	2.20	1.90
27	1.60	1.50	1.80	3.50	3.90	4.60	2.20	2.00	2.30	2.20	1.90
28	1.60	1.50	1.80	3.50	3.90	4.60	2.20	2.00	2.30	2.20	1.90
29	1.60	.....	1.80	3.50	4.00	4.70	2.20	2.00	2.20	2.20	1.90
30	1.60	.....	1.80	3.50	4.00	.....	2.20	2.00	2.20	2.20	1.90
31	1.60	.....	1.80	.....	4.00	.....	2.20	.....	2.20	.....	.....

From June 29 to August 4 no readings; gage out.

LOGAN RIVER AT LOGAN, UTAH.

This river rises in the elevated region west of Bear Lake and flows in a general southwesterly direction until it enters Cache Valley, when it bends northward and enters Bear River before this stream reaches its lower canyon. Logan River has a good water supply, and as soon as it appears from its canyon a number of canals divert its waters for the irrigation of a large portion of Cache Valley. The station on Logan River was established June 1, 1896, and is located in the river canyon about 2 miles east of Logan, Utah. One gage is a vertical iron post, set firmly in the middle of the river's bed and graduated to feet and tenths. A second gage rod is a wooden post driven into the ground near the north bank of the river. The bench mark for both rods is a stone 35 feet northeast of the end of the cable on the north side of the river, and is at an elevation of 14.01 feet above gage datum. It is marked by a cross chiseled on the rock and by the letters "B. M." in red paint. The equipment consists of a cable and car. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 316; 1897, Nineteenth Annual Report, Part IV, page 434; 1898, Twentieth Annual Report, Part IV, page 462. The following discharge measurements were made by J. S. Baker and G. L. Swendsen during 1899:

Discharge measurements of Logan River at Logan, Utah.

1899.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
April 22	3.10	420	July 3	4.60	1,526
May 9	3.57	628	August 5	3.52	525
May 15	3.67	750	November 1	2.82	323
May 29	3.80	931	December 2	2.75	301
June 17	4.65	1,680			

Daily gage height, in feet, of Logan River at Logan, Utah, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.55	2.50	2.50	2.55	3.05	3.70	4.75	3.55	3.10	2.90	2.80	2.75
2	2.50	2.50	2.50	2.55	3.00	3.75	4.70	3.50	3.10	2.90	2.80	2.75
3	2.50	2.50	2.45	2.55	3.00	3.80	4.65	3.50	3.10	2.90	2.80	2.75
4	2.45	2.35	2.45	2.55	3.00	4.20	4.60	3.50	3.05	2.90	2.80	2.70
5	2.45	2.30	2.45	2.60	3.10	4.45	4.50	3.50	3.05	2.90	2.80	2.75
6	2.45	2.80	2.40	2.60	3.15	4.25	4.45	3.50	3.05	2.90	2.80	2.75
7	2.50	2.50	2.45	2.65	3.20	4.15	4.40	3.50	3.05	3.90	2.80	2.75
8	2.55	2.50	2.50	2.65	3.30	4.15	4.35	3.45	3.05	2.90	2.80	2.75
9	2.50	2.50	2.50	2.75	3.65	4.20	4.30	3.40	3.05	2.90	2.80	2.75
10	2.50	2.50	2.50	2.85	3.50	4.30	4.25	3.40	3.05	2.90	2.80	2.75
11	2.50	2.50	2.45	3.00	3.60	4.50	4.20	3.35	3.00	2.90	2.80	2.75
12	2.50	2.50	2.45	3.00	3.80	4.75	4.20	3.35	3.00	2.90	2.80	2.70
13	2.50	2.50	2.45	3.00	3.75	4.65	4.15	3.35	3.00	2.90	2.80	2.70
14	2.50	2.50	2.45	3.05	3.70	4.50	4.15	3.30	3.00	2.90	2.80	2.70
15	2.50	2.50	2.45	3.05	3.65	4.45	4.10	3.30	3.00	2.90	2.80	2.70
16	2.50	2.50	2.45	3.05	3.55	4.50	4.05	3.30	3.00	2.90	2.80	2.70
17	2.50	2.45	2.45	3.05	3.50	4.65	4.00	3.25	3.00	2.90	2.80	2.70
18	2.50	2.45	2.45	3.00	3.60	4.70	4.00	3.25	3.00	2.90	2.75	2.70
19	2.50	2.45	2.45	2.95	3.65	4.90	3.95	3.20	2.95	2.90	2.75	2.65
20	2.50	2.45	2.50	2.95	3.70	5.00	3.90	3.20	2.95	2.90	2.75	2.65
21	2.50	2.45	2.50	2.95	3.60	4.85	3.85	3.20	2.96	2.90	2.75	2.60
22	2.50	2.40	2.50	3.10	3.50	4.80	3.80	3.20	2.95	2.85	2.75	2.60
23	2.40	2.35	2.50	3.30	3.55	4.75	3.80	3.15	2.95	2.85	2.75	2.75
24	2.50	2.45	2.50	3.40	3.65	4.70	3.75	3.15	2.95	2.85	2.75	2.70
25	2.50	2.45	2.65	3.30	3.70	4.70	3.75	3.15	2.95	2.85	2.75	2.70
26	2.50	2.45	2.65	3.25	3.75	4.70	3.70	3.15	2.95	2.85	2.75	2.70
27	2.50	2.45	2.60	3.20	3.85	4.65	3.70	3.10	2.90	2.85	2.75	2.70
28	2.50	2.45	2.60	3.10	3.75	4.65	3.65	3.10	2.90	2.85	2.75	2.65
29	2.50	.....	2.60	3.05	3.75	4.70	3.65	3.10	2.90	2.85	2.75	2.70
30	2.50	.....	2.60	3.10	3.80	4.75	3.60	3.10	2.90	2.80	2.75	2.70
31	2.50	.....	2.55	.....	3.70	.....	3.55	3.10	.....	2.80	.....	2.70

BEAR RIVER AT COLLINSTON, UTAH.

After entering the northern end of Cache Valley this river receives a number of important tributaries, viz, Cub Creek, Logan River, Blacksmith Fork, and Little Bear River. Below the mouth of Logan River, Bear River has cut through the northern extension of the Wasatch Range, forming what is known as its lower canyon. On its appearance from this it turns southerly and enters Great Salt Lake. A large canal was in process of construction during 1899, and next year a considerable portion of the summer flow of Bear River will be diverted by it to irrigate lands on the west side of Cache Valley. One of the most notable irrigation enterprises of the country diverts water from Bear River in the lower canyon and irrigates land principally to the westward of Malade River, the lowest of the important tributaries of Bear River. The gaging station at Collinston was established in July, 1889, and is located about 4 miles from the railroad station at Collinston, 2 miles east of the town of Fielding, Utah, and below the headworks of

the Bear River canal. The gage consists of a vertical iron rod graduated to tenths of a foot. The bench mark is a nail in an oak post 20 feet west of the gage and 20 feet north of the cable, and is at an elevation of 7.35 feet above gage datum. The equipment consists of a cable, tagged wire, and a boat. The observer is generally the ditch rider of the Bear River Canal Company, who has a house near the station. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 320; 1897, Nineteenth Annual Report, Part IV, page 435; 1898, Twentieth Annual Report, Part IV, page 460. The following measurements of discharge were made during 1899:

May 5, gage height, 4 feet; discharge, 4,438 second-feet.
June 23, gage height, 5.60 feet; discharge, 6,653 second-feet.
July 14, gage height, 4.61 feet; discharge, 4,819 second-feet.
November 29, gage height, 2.40 feet; discharge, 2,083 second-feet.

Daily gage height, in feet, of Bear River at Collinston, Utah, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.30	1.90	2.00	2.60	4.40	4.90	5.60	3.00	2.00	1.80	2.40	2.40
2	1.50	1.90	2.00	2.60	4.30	4.90	5.40	3.00	2.00	1.90	2.30	2.40
3	1.50	1.90	1.90	2.60	4.20	4.90	5.50	2.90	1.90	1.90	2.40	2.40
4	1.50	1.40	1.90	2.60	4.20	4.90	5.50	2.90	1.90	1.90	2.30	2.30
5	1.70	1.40	1.90	2.60	4.20	4.90	5.40	3.00	2.00	1.90	2.30	2.20
6	1.70	1.40	1.90	2.60	4.10	5.10	5.40	3.00	1.90	1.90	2.30	2.20
7	1.70	1.40	1.90	2.70	4.10	5.30	5.40	2.90	1.80	1.90	2.30	2.10
8	1.70	1.40	1.90	2.80	4.20	5.30	5.30	2.90	1.80	1.90	2.30	2.00
9	1.70	1.40	2.10	2.90	4.10	5.30	5.20	2.90	1.60	1.90	2.30	2.00
10	1.70	1.60	2.10	3.00	4.20	5.20	5.10	2.90	2.00	1.90	2.40	2.00
11	1.70	1.60	2.10	3.60	4.40	5.20	5.00	2.90	2.00	2.00	2.40	2.20
12	1.70	1.60	2.00	3.60	4.70	5.30	4.90	2.80	1.90	2.20	2.50	2.00
13	1.70	1.80	2.00	3.80	4.80	5.40	4.80	2.80	1.90	2.20	2.50	1.90
14	1.70	1.80	2.00	4.10	4.90	5.50	4.70	2.80	1.90	2.30	2.50	2.10
15	1.70	1.80	2.10	4.50	5.10	5.60	4.60	2.80	1.80	2.40	2.50	2.20
16	1.80	1.70	2.10	4.50	5.10	5.50	4.50	2.70	1.90	2.30	2.50	2.20
17	1.80	1.70	2.20	4.50	5.20	5.50	4.40	2.60	1.90	2.50	2.60	2.20
18	1.80	1.70	2.40	4.40	5.20	5.50	4.30	2.40	1.90	2.50	2.60	2.20
19	1.80	1.70	2.40	4.20	5.00	5.40	4.20	2.40	1.90	2.50	2.60	2.20
20	1.80	1.70	2.40	4.10	4.80	5.50	4.10	2.40	2.00	2.50	2.60	2.10
21	1.80	1.80	2.40	4.10	4.80	5.50	4.00	2.30	1.90	2.50	2.50	2.00
22	1.80	1.80	2.40	4.10	4.80	5.60	3.80	2.20	1.90	2.40	2.50	1.90
23	1.80	1.80	2.40	4.20	4.80	5.60	3.70	2.20	1.90	2.40	2.50	2.00
24	1.80	1.80	2.50	4.30	4.70	5.60	3.60	2.30	1.90	2.50	2.50	2.00
25	1.80	1.80	2.50	4.40	4.70	5.60	3.60	2.20	1.90	2.50	2.40	1.90
26	1.80	1.90	2.50	4.50	4.80	5.60	3.50	2.20	1.80	2.50	2.40	2.00
27	1.80	1.90	2.50	4.50	4.80	5.60	3.40	2.10	1.60	2.50	2.40	2.10
28	1.90	2.00	2.60	4.50	4.90	5.50	3.40	2.10	1.70	2.40	2.40	2.10
29	1.90	.....	2.60	4.50	4.90	5.60	3.30	2.10	1.70	2.40	2.40	2.20
30	1.90	.....	2.60	4.40	4.90	5.60	3.20	2.10	1.70	2.40	2.40	2.20
31	1.90	.....	2.60	.....	4.90	.....	3.10	2.00	.....	2.40	.....	2.20

OGDEN RIVER AT OGDEN, UTAH.

This river rises in the high land to the east of the Wasatch Range and flows in a general southerly direction. Passing through the Wasatch Mountains in a picturesque canyon, and appearing on the plains in the vicinity of Ogden, it shortly enters Weber River, and thus finds its way into Great Salt Lake. The present station was established in the spring of 1897, and is located at the old powder mill in the canyon, 5 miles east of Ogden and about 5 miles below the headworks of the Pioneer Electric Power Company; therefore the results do not show the amount of water used by that company. The gage is inclined and

divided into tenths of a foot. On June 22 the dam below the gage was washed out and the daily readings were not continued after that date. On June 30, 1899, the gage itself was carried away, but was reestablished on August 26. The bench mark of the new gage is the top of a large quartzite bowlder on the south side of the wagon road, about 60 feet southwest of the south end of the cable, and is at an elevation of 12.642 feet above gage datum. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 321; 1897, Nineteenth Annual Report, Part IV, page 437; 1898, Twentieth Annual Report, Part IV, page 465. The following measurements of discharge were made by W. B. Dougall and J. S. Baker in 1899:

May 2, gage height, 1.70 feet; discharge, 1,008 second-feet.[1]
May 4, gage height, 1.25 feet; discharge, 833 second-feet.
June 30, gage out; discharge, 396 second-feet.
July 12, gage height, 2.38 feet; discharge, 221 second-feet.
August 26, gage height, 1.25 feet; discharge, 72 second-feet.

Daily gage height, in feet, of Ogden River at Ogden, Utah, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	Day.	Jan.	Feb.	Mar.	Apr.	May.	June.
1....	1.40	1.50	2.50	3.80	1.90	1.40	17.....	1.60	1.60	2.00	3.10	2.60	1.40
2....	1.90	1.70	2.40	3.80	1.80	2.50	18.....	1.70	1.70	2.20	3.00	2.50	1.10
3....	1.50	1.70	2.10	3.50	1.70	2.40	19.....	1.60	1.80	2.80	2.70	2.60	1.00
4....	1.50	1.60	2.00	3.50	1.50	2.70	20.....	1.60	1.80	2.40	2.40	2.70	.80
5....	1.50	1.50	2.10	3.80	1.50	2.80	21.....	1.60	1.90	2.60	2.30	2.40	.70
6....	1.55	1.40	2.00	4.10	1.90	2.60	22.....	1.70	1.90	2.50	2.80	2.50	.....
7....	1.60	1.40	2.00	4.10	2.10	2.40	23.....	1.70	1.80	2.60	3.00	2.60	.....
8....	1.60	1.40	2.00	4.50	2.80	2.20	24.....	1.50	1.80	3.70	3.50	2.80	.....
9....	1.50	1.40	2.00	4.50	3.20	2.20	25.....	1.70	1.80	4.10	3.50	2.50	.....
10....	1.50	1.40	2.10	4.90	3.30	2.30	26.....	1.70	1.80	4.30	3.10	2.50	.....
11....	1.50	1.50	1.90	4.70	3.50	2.30	27.....	1.70	1.80	3.90	2.80	2.40	.....
12....	1.50	1.60	2.10	4.00	3.60	2.70	28.....	1.70	1.90	3.70	2.60	2.20	.....
13....	1.50	1.50	2.10	4.25	3.60	2.60	29.....	1.80	.....	3.55	2.30	2.00	.....
14....	1.40	1.50	2.10	4.00	3.50	2.40	30.....	1.70	.....	3.55	2.10	1.70	.....
15....	1.70	1.50	2.00	3.40	2.90	1.30	31.....	1.70	.....	3.50	.....	1.60	.....
16....	1.70	1.50	2.00	3.40	2.60	1.20							

Dam below washed out June 22.

WEBER RIVER AT UINTA, UTAH.

This river, like Ogden River, rises in the high country east of the Wasatch Mountains, passes through this range, and appears in the plains region in the vicinity of Ogden, where, after it receives the waters of Ogden River, it discharges into Great Salt Lake. There are a number of good reservoir sites on its upper tributaries, and within the last few years some of them have been utilized by the construction of notable storage works. The gaging station, established in October, 1899, is located in the canyon 5 miles east of Uinta, on the Union Pacific Railroad, immediately above the narrows known as Devils Gate. The gage is vertical, and is supported from above by a projecting timber placed out of reach of high water. The bench mark consists of a spike driven into the first telegraph pole in the canyon above the gage, and is at an elevation of 17.44 feet above gage

[1] At old powder-mill dam.

datum. The equipment consists of a cable, car, and tagged wire. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 324; 1897, Nineteenth Annual Report, Part IV, page 440; 1898, Twentieth Annual Report, Part IV, page 466. The following measurements of discharge were made by W. B. Dougall and J. S. Baker during 1899:

May 3, gage height, 3.20 feet; discharge, 1,857 second-feet.
May 6, gage height, 3.30 feet; discharge, 1,969 second-feet.
July 1, gage height, 4.10 feet; discharge, 2,582 second-feet.
July 10, gage height, 2.80 feet; discharge, 1,284 second-feet.

Daily gage height, in feet, of Weber River at Uinta, Utah, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	1.70	1.70	1.80	2.80	4.60	4.60	4.10	1.70	1.60	1.50
2	1.70	1.70	1.80	2.80	4.75	4.75	4.00	1.70	1.50	1.50
3	1.70	1.70	1.80	2.80	5.00	4.80	3.65	1.70	1.50	1.50
4	1.70	1.70	1.80	3.05	5.15	5.05	3.50	1.70	1.50	1.50
5	1.70	1.70	1.80	3.30	5.50	5.25	3.50	1.70	1.50	1.50
6	1.70	1.70	1.80	3.50	5.75	5.50	3.30	1.70	1.50	1.50
7	1.70	1.70	1.80	3.60	5.75	5.60	3.20	1.70	1.50	1.50
8	1.70	1.70	1.80	3.75	5.55	5.80	3.00	1.70	1.50	1.50
9	1.70	1.70	1.80	3.90	5.55	5.80	2.80	1.70	1.50	1.60
10	1.70	1.70	1.80	4.15	5.90	5.85	2.80	1.70	1.50	1.65
11	1.70	1.70	1.80	4.85	6.30	5.95	2.70	1.70	1.50	1.70
12	1.70	1.80	1.80	5.00	6.50	6.25	2.60	1.70	1.50	1.75
13	1.70	1.80	1.80	5.10	6.35	6.30	2.60	1.80	1.50	1.80
14	1.70	1.80	1.80	5.15	5.90	5.85	2.60	1.70	1.50	1.80
15	1.70	1.80	1.80	4.95	5.50	5.35	2.50	1.70	1.50	1.80
16	1.70	1.80	1.80	4.80	5.05	5.25	2.50	1.60	1.50	.....
17	1.70	1.80	1.80	4.75	4.65	5.40	2.45	1.60	1.50	.....
18	1.70	1.80	1.90	4.60	4.40	5.50	2.30	1.60	1.50	.....
19	1.70	1.80	1.90	4.00	4.30	5.80	2.30	1.60	1.50	.....
20	1.70	1.80	1.90	3.50	4.30	6.15	2.30	1.60	1.50	.....
21	1.70	1.80	1.90	3.40	4.55	6.30	2.20	1.60	1.50	.....
22	1.70	1.80	1.90	3.40	4.70	5.90	2.00	1.60	1.50	.....
23	1.70	1.80	2.10	4.80	4.85	5.15	2.00	1.60	1.50	.....
24	1.70	1.80	2.50	5.15	4.80	4.80	1.90	1.60	1.50	.....
25	1.70	1.80	3.15	5.35	5.15	4.65	1.80	1.60	1.50	.....
26	1.70	1.80	3.10	5.00	5.30	4.60	1.80	1.60	1.50	.....
27	1.70	1.80	2.85	4.30	5.25	4.35	1.80	1.60	1.50	.....
28	1.70	1.80	2.80	4.30	4.95	4.35	1.70	1.60	1.50	.....
29	1.70	.....	2.80	4.30	4.65	4.20	1.70	1.60	1.50	.....
30	1.70	.....	2.80	4.45	4.60	4.20	1.70	1.60	1.50	.....
31	1.70	.....	2.80	.....	4.60	.....	1.70	1.60	.....	.....

Station discontinued October 15.

PROVO RIVER AT PROVO, UTAH.

This river rises on the western slope of the Uinta Mountains and after receiving a number of tributaries enters what is known as Heber Valley, where considerable irrigation is practiced. After crossing this valley it passes through the Wasatch Mountains in a picturesque canyon, finally entering Utah Valley, where its summer flow is completely diverted for irrigation purposes. Its flood waters discharge into Utah Lake. The gaging station, established July 27, 1889, is located in the canyon, about 6 miles from Provo and above the head of most of the irrigation canals of Utah Valley. The diversion works of the company which develop power at the mouth of Provo Canyon for electric transmission to the mines west of Provo, are located about 5 miles above the station. The gage is inclined and fastened to stakes set in the ground. The bench mark is a stone firmly bedded in the

bank near the wagon road, about 100 feet southwest of the gage. It is marked "B. M." in black paint, and is 6.95 feet above gage datum. The channel is straight for some distance above and below the station. The bed of the river is gravel and not liable to change. The equipment consists of a cable, car, and tagged wire. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 226; 1897, Nineteenth Annual Report, Part IV, page 442; 1898, Twentieth Annual Report, Part IV, page 468. The following measurements of discharge were made by W. B. Dougall and J. S. Baker in 1899:

May 8, gage height, 4.70 feet; discharge, 496 second-feet.
June 29, gage height, 6.70 feet; discharge, 1,745 second-feet.
July 13, gage height, 5.22 feet; discharge, 535 second-feet.
August 16, gage height, 4.69 feet; discharge, 340 second-feet.
September 4, gage height, 4.60 feet; discharge, 352 second-feet.

Daily gage height, in feet, of Provo River at Provo, Utah, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	4.20	4.20	4.30	4.90	5.20	5.80	6.50	4.60	4.60	4.80
2	4.20	4.20	4.30	4.80	5.20	5.80	6.90	4.60	4.60	4.80
3	4.20	4.20	4.30	4.80	5.20	5.80	6.30	4.60	4.60	4.80
4	4.20	4.20	4.30	4.80	5.20	6.20	6.20	4.60	4.60	4.80
5	4.20	4.00	4.30	4.80	5.20	6.40	6.10	4.60	4.60	4.80
6	4.20	4.00	4.30	4.80	5.20	6.70	5.90	4.60	4.60	4.80
7	4.20	4.00	4.30	4.70	4.80	6.70	5.70	4.60	4.60	4.80
8	4.20	4.00	4.30	4.70	4.90	6.80	5.60	4.60	4.60	4.80
9	4.20	4.00	4.30	4.90	5.00	6.80	5.50	4.70	4.60	4.80
10	4.20	3.90	4.30	4.90	5.30	6.90	5.40	4.70	4.60	4.80
11	4.20	3.90	4.40	5.00	5.40	7.10	5.30	4.70	4.60	4.80
12	4.20	4.20	4.40	5.00	5.70	7.10	5.20	4.70	4.60	4.80
13	4.20	4.20	4.40	5.00	5.70	7.10	5.20	4.70	4.60	4.80
14	4.20	4.20	4.40	5.10	5.70	7.20	5.20	4.70	4.60	4.80
15	4.20	4.20	4.40	5.10	5.70	7.20	5.20	4.70	4.60	4.80
16	4.20	4.20	4.40	5.10	5.60	7.20	5.10	4.70	4.60	4.80
17	4.20	4.20	4.50	5.10	5.50	7.20	5.10	4.70	4.60	4.80
18	4.20	4.20	4.50	5.10	5.50	7.60	5.10	4.70	4.60	4.80
19	4.20	4.20	4.80	5.20	5.50	7.70	5.00	4.70	4.60	4.80
20	4.20	4.20	5.00	5.20	5.50	7.80	5.00	4.60	4.60	4.80
21	4.20	4.20	5.00	5.30	5.50	7.90	5.00	4.60	4.60	4.80
22	4.20	4.20	5.00	5.30	5.30	8.00	5.00	4.60	4.60	.....
23	4.20	4.20	5.00	5.30	5.30	7.60	4.90	4.60	4.60	.....
24	4.20	4.20	5.30	5.30	5.30	7.60	4.90	4.60	(a)	.....
25	4.20	4.20	5.30	5.30	5.60	7.40	4.90	4.60	(a)	.....
26	4.20	4.20	5.00	5.30	5.80	7.40	4.80	4.60	(a)	.....
27	4.20	4.20	5.00	5.20	5.80	7.20	4.80	4.60	(a)	.....
28	4.20	4.20	5.00	5.20	5.80	7.10	4.80	4.60	(a)	.....
29	4.20	.....	5.00	5.20	5.80	6.70	4.80	4.60	(a)	.....
30	4.20	.....	5.00	5.20	5.80	6.60	4.60	4.60	(a)	.....
31	4.20	.....	5.00	.....	5.80	.....	4.60	4.60	.....	.....

a No reading. Station discontinued October 21.

UTAH LAKE.

This fresh-water lake receives the surplus waters and seepage of a number of streams that receive their water supply from the Wasatch Mountains, the principal ones being Currant Creek, Spanish Fork, Hobble Creek, Provo River, and American Fork. The ordinary flow of these streams is diverted, on their appearance from their canyons, to irrigate the lands of Utah Valley. A gaging station has been maintained on Provo River, as described on page 338 of this report. A number of miscellaneous measurements were made during 1899 on

the other tributaries as well as on the canals diverting water from the same during the last season. On May 11 Spanish Fork, at the second bridge in the canyon, was discharging 679 second-feet; May 10, Hobble Creek, at the second bridge in the canyon, above Springville, was discharging 244 second-feet; American Fork, on May 9, was carrying 106 second-feet, with a gage height of 0.1 foot, on a temporary gage established that day. The following table shows the discharge of a number of canals in Utah County as determined by J. S. Baker:

Discharge of canals in Utah County, Utah.

1899.

Date.	Stream.	Source.	Discharge.	Remarks.
			Sec.-feet.	
June 22	Boxelder Creek	Mountain springs..	31.46	
Aug. 16	Timpanogas canal...	Provo River	10.40	
Aug. 16	Timpanogas canal...	Provo River	7.84	9,500 feet below last measurement.
Aug. 17	Little Dry Creek canal.	Provo River	4.64	
Aug. 17	Tanner's race	Provo River	16.94	
Aug. 17	Lake Bottom canal..	Provo River	7.14	
Aug. 17	West Union canal...	Provo River	55.98	
Aug. 17	Provo Bench canal..	Provo River	53.65	
Aug. 17	Provo Bench canal..	Provo River	57.96	1½ miles above last measurement.
Aug. 17	Park & Nuttall's ditch.	Provo River	11.84	
Aug. 17	Upper East Union canal.	Provo River	28.27	
Aug. 17	Upper East Union canal.	Provo River	27.52	1 mile below last measurement.
Aug. 18	City race.....	Provo River	12.40	
Aug. 18	Factory race.....	Provo River	51.44	
Aug. 18	East Union canal ...	Provo River	18.22	
Aug. 18	Bomb & Richardson's canal.	Provo River	1.00	Estimated.
Aug. 18	Stubbs & Furgeson's canal.	Provo River	5.00	By floats.
Aug. 18	Richmond & Penrod's canal.	Provo River	4.00	Estimated.
Aug. 21	Mapleton Union canal.	Hobble Creek.....	19.11	
Aug. 21	Mapleton Union canal.	Hobble Creek.....	17.95	1 mile above last measurement.
Aug. 21	Mapleton reservoir canal.	Hobble Creek.....	3.09	
Aug. 21	Mapleton reservoir canal.	Hobble Creek.....	2.73	One-half mile above last measurement.
Aug. 21	North Bench canal..	Hobble Creek.....	8.35	
Aug. 21	North Bench canal..	Hobble Creek.....	8.39	Three-fourths mile below last measurement.
Aug. 21	Island canal.....	Hobble Creek.....	4.02	
Aug. 21	Sage Creek canal....	Hobble Creek.....	5.96	
Aug. 21	South Big Field ditch	Hobble Creek.....	5.52	
Aug. 21	City ditch.....	Hobble Creek.....	2.21	
Aug. 22	City canal.....	Spanish Fork	38.51	
Aug. 22	Salem Irrigation Company's canal.	Spanish Fork	22.05	
Aug. 22	South Field Irrigation Company's canal.	Spanish Fork	37.39	

Discharge of canals in Utah County, Utah—Continued.

1899—Continued.

Date.	Stream.	Source.	Discharge.	Remarks.
			Sec.-feet.	
Aug. 22	East Bench canal...	Spanish Fork.....	28.19	
Aug. 22	Lake Shore canal...	Spanish Fork.....	12.43	
Aug. 22	Salem Pond canal...	Low springs	4.99	
Aug. 23	Summit Creek.....	Mountain springs..	14.64	
Aug. 23	Spring Lake Creek..	Low springs	2.89	
Aug. 25	American Fork canal.	American Fork....	28.85	
Aug. 25	Lehi canal.....	American Fork....	17.82	
Aug. 25	Pleasant Grove canal	American Fork....	10.71	

NOTE.—All measurements were made by current meter unless otherwise stated.

A station has been maintained on Utah Lake at Geneva, where has been recorded the rise and fall of the water surface since November 6, 1896. The gage consists of a vertical rod attached to one end of a bath house at that point. The bench mark of the lake commissioners, a sandstone monument at the edge of the bluff opposite the south end of the pavilion, is 18.644 feet above gage datum, which was placed 4 feet below compromise point. The results of observations at this station will be found as follows: 1896, Eighteenth Annual Report, Part IV, page 330; 1897, Nineteenth Annual Report, Part IV, page 443; 1898, Twentieth Annual Report, Part IV, page 467.

Daily gage height, in feet, of Utah Lake at Geneva, Utah, for 1899.

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	0.60	0.80	.....	1.50	.....	.....	1.70	.....	.....
2	.....	.....	.....	.....	.....	.....	.....	.....	0.60
3	.....	.....	1.30	.....	.....	2.25	.....	.....	.....
4	.65	.85	.....	1.50	.....	.....	.....	1.05	.....
5	.....	.....	.....	.....	1.70	2.00	1.50	.....	.....
6	.65	.90	1.35	1.55	.....	.....	.....	.95	.....
7	.....	.....	.....	.....	.....	.....	1.50	.....	.30
8	.....	.....	1.35	1.50	1.85	2.15	.....	.....	.....
9	.60	.95	.....	.....	.....	.....	.....	1.00	.....
10	.....	.....	1.35	1.50	1.90	2.10	1.55	.....	.10
11	.60	1.00	.....	.....	.....	.....	.....	.90	.....
12	.....	.....	.....	.....	.....	2.10	1.50	.....	.....
13	.65	1.00	1.40	1.55	.....	.....	.....	.....	.....
14	.....	.....	.....	.....	2.00	.....	1.40	.90	.20
15	.70	.....	1.45	.....	.....	2.00	.....	.....	.....
16	.....	1.00	.....	.....	.....	.....	.....	.80	.....
17	.....	.....	1.40	.....	2.10	1.90	1.40	.....	.....
18	.70	1.05	.....	.....	.....	.....	.....	.80	.....
19	.....	.....	.....	.....	2.20	.....	1.30	.....	.....
20	.....	1.05	1.40	1.55	.....	.....	.....	.....	.....
21	.....	.....	.....	.....	2.15	.....	1.25	.....	.....
22	.....	.....	1.45	1.60	.....	1.80	.....	.....	.....
23	.....	1.05	.....	.....	.....	.....	.....	.75	.....
24	.....	.....	1.45	1.60	.....	1.80	1.20	.....	.....
25	.70	.....	.....	.....	.....	.....	.....	.70	.....
26	.....	.....	.....	.....	2.20	.....	1.15	.....	.....
27	.75	.....	1.50	1.70	.....	.....	.....	.70	.....
28	.....	.....	.....	.....	.....	.....	1.10	.....	.....
29	.....	1.25	1.50	1.65	.....	1.75	.....	.....	.....
30	.....	.....	.....	.....	2.20	.....	.....	.65	.....
31	.....	1.30	.....	1.65	.....	.....	1.10	.....	.....

Station discontinued October 14.

JORDAN RIVER.

Utah Lake discharges toward the north through Jordan River, which empties into Great Salt Lake. A number of large canals divert the waters of this stream and supply lands in Salt Lake County, one of them taking water to Salt Lake City. Measurements of the flow of Jordan River and the amount diverted into the canals have not been made systematically, owing largely to conservatism or distrust. When the hydrographic investigations were begun in 1889, an attempt was made on behalf of the Geological Survey to secure cooperation, or at least the sympathy of the persons interested, but there appeared to be a sentiment against obtaining records of this character, due possibly to the fear that private interests might be injured. There was a tacit agreement at least that it was better not to meddle with the systems in vogue. Even ten years later, when attempts were made by the city engineer to obtain weir measurements of the canals, these were opposed and the weirs destroyed. The conditions, however, have become so onerous that a private corporation has taken upon itself the measurement of the river, systematic observations being begun in May, 1899.

The plant of the Salt Lake City Water and Electrical Power Company was completed in 1899, and is developing electric power which is used in the mining camps of Bingham and Mercur, Utah. The plant is located on Jordan River, about 20 miles south of Salt Lake City and 9 miles below the outlet of Utah Lake. This water-power company has been keeping a record of the discharge of Jordan River and of the various canals diverting water immediately above, but on account of pending lawsuits the data are not at present available. The water necessary to develop the power of this plant is diverted from Utah and Salt Lake canal, which heads about 2 miles above the plant, at what is known as the Point of the Mountain. It is taken from the west side of the river, at the same diversion point where the East Jordan canal diverts water to the east side. When the power house is reached, an elevation of about 73 feet above the river has been attained by both canals, and this is the fall that is at present utilized. Halfway between the above-described dam and the power house there is a second dam across the river, from which two canals divert water—the City canal on the east side and the South Jordan canal on the west side. At the power plant, 1 mile below, these two canals have attained elevations of about 20 feet above the river. On December 6, 1899, measurements of the discharge of these canals, as well as of Jordan River, were made by Cyrus C. Babb at the gaging stations of the Salt Lake City Water and Electrical Power Company. Utah and Salt Lake canal below the power company's diversion, at a gage height of 2.40 feet, was discharging 27 second-feet; Utah and Salt Lake canal, above the power company's diversion, at a gage height of 4.13 feet, was di-

charging 80 second-feet; the South Jordan canal, at a gage height of 2.33 feet, was discharging 19 second-feet; Jordan canal, at a gage height of 4.15 feet, was carrying 111 second-feet; City canal, at a gage height of 3.20 feet, was discharging 45 second-feet; East Jordan canal, with a gage height of 1.02 feet, was discharging 6 second-feet. A measurement was also made of the tailrace of the power plant, in order to compare it with the difference in the two measurements of Utah and Salt Lake canal, and a discharge of 56 second-feet was found.

The city engineer of Salt Lake City, Mr. Frank C. Kelsey, has been keeping a record of the discharge of various small streams in the vicinity of Salt Lake City, in connection with the city water supply. The following are the creeks, with the drainage areas in their respective canyons: Little Cottonwood Creek, 27.72 square miles; Big Cottonwood Creek, 48.47 square miles; Mill Creek, 21.29 square miles; Parleys Creek, 50.14 square miles; Emigration Creek, 18.92 square miles; Red Butte Creek, 11.59 square miles; City Creek, 19.15 square miles.

On Little Cottonwood Creek measurements are taken twice a day of the height of water passing over a Cippoletti weir 18 feet long. The record is from November 11, 1898, to May 20, 1899. At this latter date the weir was washed out by a flood and funds could not be procured to replace it.

The station on Big Cottonwood Creek is placed below the Utah Power Company's building. A record was commenced on October 30, 1898, the measurements being taken over a rectangular weir 16 feet long.

The measurements on Mill Creek were started September 8, 1898, and are made over a Cippoletti weir placed in the canyon. April 10, 1899, this weir was removed by the water master of the district, but was replaced on the 30th of the same month.

There is an interesting double Cippoletti weir on Parleys Creek, which is so controlled that the entire weir can be lifted, allowing the gravel and deposit from above to be washed out from time to time. The records from this point are fragmentary and were not obtained by this office.

Daily mean discharge, in second-feet, of Little Cottonwood Creek near Salt Lake City, Utah, for 1898.

[Drainage area, 27.72 square miles.]

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1	.....	14	8	.....	12	14	13	14	20	12	12	26	10	12
2	.....	13	9	.....	11	15	13	12	21	10	11	27	13	12
3	.....	10	10	.....	12	16	11	11	22	11	10	28	14	13
4	.....	10	11	12	13	17	11	12	23	14	11	29	15	12
5	.....	13	12	12	13	18	11	12	24	14	13	30	14	11
6	.....	11	13	13	13	19	11	12	25	9	12	31	.....	12
7	.....	11												

Daily mean discharge, in second-feet, of Little Cottonwood Creek near Salt Lake City, Utah, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	Day.	Jan.	Feb.	Mar.	Apr.	May.
1	12	12	13	13	52	17	10	12	13	50	121
2	12	12	12	14	48	18	12	12	13	53	121
3	12	11	11	13	46	19	13	12	13	50	120
4	12	10	10	14	44	20	13	12	13	46	120
5	13	9	10	14	44	21	12	12	13	48	.....
6	12	9	13	13	48	22	12	11	12	54	.....
7	13	11	12	14	47	23	11	12	13	54	.....
8	14	12	12	15	53	24	12	12	13	64	.....
9	12	9	13	18	65	25	12	12	14	64	.....
10	12	9	12	23	72	26	12	12	14	63	.....
11	12	11	12	30	92	27	12	12	13	61	.....
12	12	11	12	34	119	28	12	12	13	55	.....
13	12	13	12	41	146	29	12	.....	13	52	.....
14	12	12	12	41	149	30	12	.....	13	51	.....
15	12	12	12	46	135	31	12	.....	13	.....	.....
16	11	12	12	51	120						

May 21 weir washed out and not replaced.

Daily mean discharge, in second-feet, of Big Cottonwood Creek near Salt Lake City, Utah, for 1898.

[Drainage area, 48.47 square miles.]

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1	.....	34	36	12	.....	31	26	22	.....	35	19
2	.....	34	36	13	.....	33	30	23	.....	33	20
3	.....	36	30	14	.....	32	30	24	.....	33	16
4	.....	36	30	15	.....	32	21	25	.....	31	19
5	.....	35	33	16	.....	33	21	26	.....	31	18
6	.....	35	32	17	.....	31	22	27	.....	31	21
7	.....	34	31	18	.....	34	21	28	.....	33	.....
8	.....	35	29	19	.....	33	20	29	.....	37	.....
9	.....	27	31	20	.....	30	21	30	34	36	.....
10	.....	30	29	21	.....	32	19	31	33	.....	.....
11	.....	32	26								

Daily mean discharge, in second-feet, of Big Cottonwood Creek near Salt Lake City, Utah, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.
1	.....	25	26	36	78	211	240	71
2	.....	26	28	36	74	220	218	68
3	.....	21	26	35	68	237	204	70
4	.....	18	27	35	67	320	203	72
5	.....	12	25	42	68	335	207	71
6	.....	12	28	43	77	326	202	72
7	.....	13	29	47	93	326	182	73
8	.....	19	32	53	108	335	174	68
9	.....	9	37	68	141	377	170	63
10	.....	34	30	83	154	407	168	61
11	.....	29	31	114	180	560	157	61
12	.....	27	29	102	231	682	165	58
13	.....	26	30	135	263	593	154	57
14	.....	28	29	127	260	481	147	58
15	22	27	31	130	236	472	134	58
16	21	27	30	140	217	479	137	62
17	26	29	31	134	212	494	128	.....
18	25	28	32	130	214	528	121	.....
19	25	27	30	105	215	561	117	.....
20	24	27	31	92	216	567	115	.....
21	25	28	29	87	188	387	112	.....
22	26	26	31	112	173	301	105	.....
23	24	27	32	130	183	276	96	.....
24	25	27	39	150	228	267	94	.....
25	25	26	43	147	258	278	90	.....
26	25	25	44	135	254	254	88	.....
27	25	26	40	121	266	244	85	.....
28	29	26	37	103	240	244	84	.....
29	25	.....	35	89	225	246	80	.....
30	26	.....	35	83	211	246	82	.....
31	26	.....	36	.....	198	.....	76	.....

Daily mean discharge, in second-feet, of Mill Creek near Salt Lake City, Utah, for 1898.

[Drainage area, 21.29 square miles.]

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1	.....	14	8	.....	8	14	14	10	20	11	13	26	10	12
2	.....	13	9	.....	8	15	12	13	21	10	14	27	13	13
3	.....	9	10	.....	8	16	13	13	22	14	13	28	14	13
4	.....	9	11	14	8	17	13	13	23	14	12	29	14	12
5	.....	13	12	13	8	18	13	13	24	12	13	30	14	11
6	.....	10	13	14	8	19	12	13	25	11	13	31	.....	12
7	.....	6												

Daily mean discharge, in second-feet, of Mill Creek near Salt Lake City, Utah, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1	12	12	12	12	24	35	36	20	17	12	14
2	12	12	12	13	26	38	34	20	17	12	14
3	13	12	12	13	25	41	32	20	17	12	14
4	12	5	12	13	24	46	32	20	17	12	14
5	12	3	12	14	23	60	32	19	17	12	14
6	12	3	12	15	25	51	30	19	17	12	14
7	12	3	12	15	27	46	30	19	17	12	14
8	12	7	12	22	31	53	27	19	17	14	14
9	12	8	13	22	36	55	27	19	17	14	14
10	12	12	12	.....	31	56	27	18	17	14	14
11	12	12	12	.....	39	57	27	18	17	14	14
12	12	12	12	.....	43	60	25	18	15	14	13
13	12	12	12	.....	47	66	25	18	15	14	13
14	12	12	12	.....	47	66	25	18	15	14	13
15	12	12	12	.....	42	62	25	18	15	14	13
16	12	12	12	.....	40	59	25	18	15	14	.....
17	12	12	12	.....	38	66	25	18	15	14	.....
18	12	12	12	.....	40	60	25	18	15	14	.....
19	12	12	12	.....	40	56	25	18	15	14	.....
20	12	12	12	.....	35	56	25	18	15	14	.....
21	12	12	12	.....	32	56	25	18	15	14	.....
22	12	12	12	.....	33	48	22	18	15	14	.....
23	8	12	12	.....	35	46	22	18	15	14	.....
24	12	12	12	.....	37	45	22	17	15	14	.....
25	12	12	14	.....	37	41	22	17	15	14	.....
26	12	12	15	.....	41	40	22	17	15	14	.....
27	12	12	14	.....	42	38	21	17	15	14	.....
28	12	12	18	.....	40	37	21	17	15	18	.....
29	12	.....	18	.....	42	40	21	17	15	18	.....
30	12	.....	12	25	36	40	20	17	15	18	.....
31	12	.....	13	.....	34	.....	20	17	.....	18	.....

April 10 weir removed by water master; replaced April 30.

GREAT SALT LAKE.

Streams that contribute water to this lake have their sources in the Wasatch Mountains. The lake is very shallow, not averaging 20 feet, while the deepest point is only 60 feet. The western and eastern shores slope very gradually, and the fall of a foot will expose many square miles, while a rise of 6 feet would cover nearly one-tenth more area. At ordinary stages the area of the lake itself is about 2,280 square miles. A record of the fluctuations of the surface has been maintained since 1875, and they are published below, referred to Garfield Beach gage. The table published in the Thirteenth Annual Report, Part III, page 20, refers to the shore gage, which datum is 4.6 feet above Garfield Beach gage. A further description of the fluctuations of this lake will be found in Monograph I of the United States Geological Survey, entitled Lake Bonneville, by G. K. Gilbert, pages 233 to 238.

Gage heights of Great Salt Lake, referred to Garfield Beach gage.

Date.	Gage height.	Date.	Gage height.
1875.	*Feet.*	1880—Continued.	*Feet.*
September 14	10.4	July 13	7.9
September 22	10.3	July 30	7.7
September 25	10.3	August 14	7.5
October 6	10.2	August 29	7.3
October 12	10.2	September 14	7.0
October 18	10.2	September 29	6.8
October 26	10.1	October 15	6.6
November 9	10.0	October 29	6.5
November 16	10.0	November 12	6.3
November 23	10.2	November 29	6.3
November 29	10.3	December 11	6.3
December 7	10.3	December 14	6.3
December 14	10.3	December 27	6.4
December 21	10.4	1881.	
1876.		January 14	6.4
January 5	10.5	January 28	6.8
January 11	10.6	February 14	7.1
January 29	10.6	February 28	7.1
February 1	10.6	March 14	7.2
February 15	10.7	April 1	7.2
February 22	10.7	April 16	7.3
March 15	10.8	May 1	7.6
March 22	10.9	May 16	7.9
March 28	10.9	June 1	8.0
April 17	11.0	June 16	8.0
April 25	11.1	July 1	7.8
May 2	11.2	July 16	7.8
May 22	11.6	July 23	7.7
June 2	11.8	August 2	7.5
June 8	11.9	August 19	7.3
June 13	12.0	September 8	7.0
June 23	12.2	September 16	7.9
June 30	12.4	October 2	6.7
July 18	12.1	October 16	6.7
July 25	12.2	November 2	6.6
August 1	12.1	November 16	6.6
August 10	12.0	December 1	6.6
August 22	11.6	December 15	6.7
August 29	11.5	1882.	
August 30	11.5	January 2	6.7
September 14	11.5	January 16	6.8
September 19	11.4	February 2	6.8
September 26	11.4	February 16	6.9
October 9	11.3	March 2	6.9
1877.		March 21	7.0
July 12	12.9	April 1	7.2
October 19	11.7	April 16	7.2
November 24	10.4	May 2	7.4
1878.		May 16	7.5
January 21	10.5	June 2	7.5
March 28	10.6	June 16	7.5
May—	10.8	July 2	7.3
June 30	10.9	July 17	7.2
July 18	10.7	August 2	7.0
November 1	9.4	August 15	6.8
December 11	9.3	September 2	6.4
1879.		September 16	6.2
May 2	9.6	October 2	6.1
November 19	7.1	October 15	6.0
December 2	7.1	December 15	6.0
December 16	7.2	December 30	6.0
December 31	7.3	1883.	
1880.		January 15	6.0
January 14	7.4	January 30	6.0
January 29	7.2	February 15	6.1
February 23	7.2	February 30	6.1
March 10	7.4	March 15	6.1
March 30	7.4	April 2	6.3
April 15	7.5	September 3	6.5
April 28	7.6	September 16	6.1
May 12	7.7	October 3	5.6
May 26	7.9	October 15	5.4
June 10	7.9	November 1	5.2
June 28	8.0	November 15	5.0
		December 2	5.0
		December 15	5.0

Gage heights of Great Salt Lake, referred to Garfield Beach gage—Continued.

Date.	Gage height.	Date.	Gage height.
1884.	*Feet.*	1887—Continued.	*Feet.*
January 2	5.0	July 14	8.4
January 15	5.0	August 6	8.1
February 2	5.0	September 5	7.7
February 15	5.1	September 20	7.3
March 1	5.2	October 4	7.3
March 15	5.5	October 25	7.1
April 1	5.6	November 11	7.1
April 15	5.9	1888.	
May 2	6.2	January 1	7.1
May 15	6.5	January 10	7.2
June 1	7.0	February 1	7.2
June 15	7.2	February 24	7.3
July 1	7.4	March 3	7.3
July 15	7.4	March 23	7.5
August 2	7.2	April 6	7.6
August 15	7.0	May 8	7.4
September 1	7.0	May 30	7.5
September 15	7.0	June 22	7.3
October 2	7.0	July 3	7.1
October 15	6.9	July 23	6.8
November 1	6.9	August 1	6.7
November 15	6.8	August 16	7.5
December 2	6.8	September 1	6.3
December 15	6.9	September 15	6.1
1885.		October 1	5.9
January 2	7.1	November 1	5.4
January 15	7.2	November 10	5.6
February 2	7.3	December 10	5.6
February 16	7.4	1889.	
March 2	7.5	January 1	5.6
March 16	7.7	January 15	5.6
April 3	7.8	February 1	5.7
April 16	7.9	February 15	5.8
May 2	8.1	March 1	6.0
May 15	8.2	March 25	6.1
June 1	8.5	April 15	6.8
June 16	8.7	May 1	5.9
July 2	8.8	May 20	5.8
July 15	8.8	June 1	5.7
August 2	8.6	June 25	5.4
August 15	8.6	July 12	4.9
September 2	8.2	August 10	4.5
September 15	8.0	August 30	4.1
October 2	8.0	September 23	3.6
October 15	7.9	October 12	3.6
November 1	7.9	December 14	3.7
November 15	7.7	1890.	
December 2	7.7	January 4	3.8
December 15	7.9	February 1	4.2
1886.		February 15	4.3
January 2	8.0	March 6	4.5
January 15	8.1	March 28	4.8
February 2	8.3	April 15	4.8
February 15	8.4	May 6	5.3
March 2	8.6	June 14	5.6
March 15	8.7	June 27	5.6
April 1	8.8	July 17	5.4
April 15	8.9	August 2	5.2
May 2	9.0	August 12	4.9
May 15	9.1	September 11	4.6
June 2	9.2	October 13	4.2
July 29	8.8	November 5	4.2
October 2	8.2	December 12	4.2
November 6	8.0	1891.	
December 28	8.2	January 5	4.3
1887.		January 30	4.3
February 5	8.1	February 18	4.3
March 5	8.3	March 2	4.6
March 19	8.4	March 16	4.6
April 2	8.4	April 2	4.7
April 16	8.5	April 15	4.7
May 7	8.4	May 1	4.9
May 22	8.7	June 2	5.0
May 30	8.7	August 15	4.3
June 10	8.7	September 9	4.3
June 22	8.6	September 19	3.9
July 4	8.5		

Gage heights of Great Salt Lake, referred to Garfield Beach gage—Continued.

Date.	Gage height.	Date.	Gage height.
1891—Continued.	*Feet.*	1897—Continued.	*Feet.*
October 5	3.9	April 15	3.2
October 17	3.8	May 1	3.4
November 2	3.9	May 15	3.6
November 18	3.8	June 1	3.8
December 1	3.8	June 15	3.7
December 16	3.8	July 1	3.5
1892.		July 15	3.3
January 1	3.8	August 1	3.
1893.		August 15	2.7
January 1	3.2	September 1	2.7
January 14	3.3	September 15	2.3
January 30	3.4	October 1	2.2
February 14	3.5	October 15	2.2
February 28	3.5	November 1	2.
March 14	3.7	November 15	2.
March 30	3.9	December 1	2.1
April 14	4.1	December 15	2.2
April 29	4.3	1898.	
May 13	4.5	January 1	2.3
May 29	4.5	January 15	2.4
June 15	4.5	February 1	2.4
July 1	4.3	February 15	2.5
July 15	4.2	March 1	2.7
July 31	3.5	March 15	2.8
August 15	3.3	April 1	2.9
August 30	3.3	April 15	3.1
September 15	3.0	May 1	3.2
September 30	2.8	May 15	3.3
October 1	2.5	June 1	3.4
1894.		June 15	3.3
January 3	3.0	July 1	3.3
January 30	3.2	July 15	3.1
February 14	3.1	August 1	2.8
February 28	3.1	August 15	2.6
March 14	3.3	September 1	2.2
March 31	3.6	September 15	1.9
April 14	3.8	October 1	1.8
April 30	4.0	October 15	1.7
May 31	4.5	November 1	1.5
August 16	3.8	November 15	1.4
October 1	3.4	December 1	1.3
November 1	3.1	December 15	1.3
1896.		1899.	
January 1	2.3	January 1	1.4
February 1	2.5	January 15	1.5
March 1	2.6	February 1	1.7
April 1	2.8	February 15	1.8
May 1	2.8	March 1	2.0
June 1	3.3	March 15	2.1
July 1	3.3	April 1	2.3
August 1	2.8	April 15	2.3
September 1	2.4	May 1	2.4
October 1	2.2	May 15	2.6
November 1	1.9	June 1	2.7
December 1	2.0	June 15	2.8
1897.		July 1	2.7
January 1	2.3	July 15	2.6
January 15	2.4	August 1	2.3
February 1	2.5	August 15	2.1
February 15	2.6	September 1	2.0
March 1	2.8	September 15	1.8
March 15	2.9	October 1	1.7
April 1	3.1	October 15	1.6
		November 1	1.7
		November 15	1.6
		December 1	1.4
		December 15	1.4

SNAKE RIVER AT GROVANT, WYOMING.

This river rises on the southern slope of the Continental Divide, in the Yellowstone National Park, draining the country west and southwest of Yellowstone Lake. From Shoshone, Lewes, and Heart lakes, near its head, the river flows in a southerly direction through a timbered and mountainous country, resulting in a long period of high water. After continuing through this area for about 20 miles it broadens into Jackson Lake, a deep body of water about 3 miles wide and 8 miles long. Below the lake the river flows through Jackson Hole Valley—about 40 miles long and 8 miles wide—and then enters a long canyon near the Idaho-Wyoming line. All of the large tributaries come from the east, receiving their waters from the Wind River Range. The west side of the valley is bounded by the high Teton Mountains, from which most of the drainage flows westward through Teton River into North Fork of Snake River.

This area has been mapped in part by T. M. Bannon, who states that about 8,000 acres can be irrigated in Jackson Hole Valley. To do this will necessitate the construction of five or six canals, owing to the position of the agricultural lands. The small area now irrigated is watered by ditches, usually constructed by individuals and at little cost beyond the labor. Cultivation is confined to small gardens and forage crops, the latter for winter feed of the stock that range in the country during the summer season. During the winter the snow is so deep that the cattle must be fed for from three to five months.

The river station at Grovant was established April 2, 1899, by T. M. Bannon, at Menors Ferry, the location being shown on the Grand Teton atlas sheet. A bench mark is located near Mr. Menor's house, west of the gage rod. The elevation of the bench mark is 6,457.864 feet above sea level. The 5-foot mark on the gage rod is at an elevation of 6,448.483 feet. The channel above and below the ferry is straight and the bank sufficiently high to confine flood waters, this being about the only place of this kind in the valley. The bed of the stream is of gravel. The place is most readily reached by hired conveyance from St. Anthony, Idaho. The road crosses the North Fork of Snake River and the Teton River at the lower end of Teton Basin. Measurements can readily be made at these localities, particularly at the latter, where there is a stage station.

No measurements of discharge were made at this point during 1899.

Daily gage height, in feet, of Snake River at Grovant, Wyoming, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	.....	0.44	2.75	6.66	2.75	0.75	0.25
2	0.02	.40	2.88	6.58	2.50	.75	.25
3	.04	.33	3.00	6.42	2.50	.75	.25
4	.06	.35	3.42	6.25	2.42	.75	.25
5	.10	.42	3.58	6.17	2.33	.75	.17
6	.10	.44	3.42	6.00	2.25	.67	.17
7	.10	.50	3.33	5.92	2.17	.67	.17
8	.13	.60	3.33	5.83	2.08	.67	.17
9	.15	.83	3.50	5.75	2.17	.67	.17
10	.18	.92	3.75	5.58	2.08	.67	.17
11	.13	1.17	4.08	5.50	2.00	.58	.17
12	.17	1.08	4.50	5.33	1.92	.58	.13
13	.25	1.17	4.50	5.50	1.83	.58	.13
14	.25	1.25	4.25	5.42	1.75	.58	.13
15	.25	1.33	4.33	5.17	1.67	.58	.17
16	.25	1.42	4.67	4.83	1.58	.50	.17
17	.23	1.42	5.08	4.67	1.50	.50	.21
18	.21	1.50	5.75	4.50	1.42	.50	.21
19	.21	1.67	6.25	4.33	1.33	.50	.25
20	.19	1.83	6.75	4.25	1.33	.42	.25
21	.23	1.83	6.83	4.17	1.25	.42	.29
22	.21	1.83	6.50	4.17	1.25	.42	.....
23	.23	1.75	6.25	4.00	1.17	.42	.....
24	.38	1.83	6.25	3.67	1.17	.42	.....
25	.52	2.08	6.13	3.42	1.08	.42	.....
26	.58	2.33	6.34	3.25	1.00	.42	.....
27	.54	2.42	6.41	3.17	.92	.33	.....
28	.46	2.50	6.41	3.17	.92	.33	.....
29	.44	2.67	6.63	3.00	.83	.33	.....
30	.42	2.83	6.75	3.00	.83	.33	.....
31	.....	2.75	.....	2.92	.75	.....	.....

Closed for winter October 21.

PORTNEUF RIVER AT POCATELLO, IDAHO.

This river is a tributary of Snake River, and rises in southeastern Idaho, its headwater tributaries draining the area immediately west of those of Blackfoot River. Its basin is almost wholly included within the Fort Hall Indian Reservation. There is little agricultural country along its course until Pocatello is reached, where the valley broadens to a considerable extent. This river will probably not be developed for irrigation purposes by private capital until the reservation is thrown open for settlement. The gaging station at Pocatello was established May 8, 1897, and is located at the wagon bridge one-eighth of a mile below the plant of the Pocatello Electric Power Company. The rod is vertical and is securely spiked to the west abutment of the bridge. The bench mark is a spike driven into the end of a log on the east abutment of the bridge, and is opposite the 13-foot mark. The channel above the station is curved, while below it is straight. The right bank is high, but the left is liable to overflow at a 12-foot gage height. The bed of the stream is rocky. The results of measurements may be found as follows: 1897–98, Twentieth Annual Report, Part IV, page 474. The following discharge measurements were made by F. S. Shirley and N. S. Dils during 1899:

March 30, gage height, 8 feet; discharge, 368 second-feet.
May 22, gage height, 9.10 feet; discharge, 614 second-feet.
June 25, gage height, 8.90 feet; discharge, 558 second-feet.
July 28, gage height, 7 feet; discharge, 123 second-feet.
August 27, gage height, 7.05 feet; discharge, 129 second-feet.

Daily gage height, in feet, of Portneuf River at Pocatello, Idaho, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	7.60	7.40	7.30	7.75	8.55	9.50	8.00	(a)	6.80	7.00
2	7.60	7.30	7.30	7.80	8.55	9.50	8.00	(a)	6.70	7.00
3	7.60	7.30	7.30	7.80	8.50	9.55	8.10	(a)	6.70	7.00
4	7.50	7.30	7.30	7.80	8.50	9.55	8.00	(a)	6.90	7.00
5	7.50	7.30	7.30	7.95	8.55	9.60	8.00	(a)	7.00	7.00
6	7.50	7.30	7.30	8.00	8.45	9.65	7.90	(a)	7.15	7.00
7	7.50	7.30	7.40	8.00	8.55	9.60	8.00	(a)	7.20	7.00
8	7.50	7.40	7.40	8.15	8.70	9.55	8.00	(a)	7.25	7.20
9	7.50	7.50	7.50	8.35	8.85	9.40	8.00	(a)	7.20	7.20
10	7.50	7.60	7.50	8.50	9.15	9.40	8.00	(a)	7.20	7.20
11	7.50	7.60	7.50	8.50	9.40	9.45	8.10	(a)	7.10	7.20
12	7.50	7.50	7.50	8.60	9.80	9.30	8.10	(a)	7.00	7.20
13	7.50	7.40	7.50	8.60	9.75	9.40	8.10	(a)	7.00	7.20
14	7.50	7.30	7.50	8.70	9.50	9.35	7.80	(a)	7.00	7.20
15	7.50	7.40	7.50	8.55	9.70	9.15	6.70	(a)	7.20	.....
16	7.60	7.50	7.50	8.55	(a)	9.05	7.80	(a)	7.00	.....
17	7.60	7.60	7.50	8.60	(a)	9.10	8.00	(a)	7.00	.....
18	7.50	7.70	7.50	8.55	(a)	9.00	8.00	(a)	7.00	.....
19	7.40	7.70	7.50	8.55	(a)	9.15	7.20	(a)	6.90	.....
20	7.40	7.60	7.50	8.40	(a)	9.25	7.00	(a)	6.90	.....
21	7.40	7.50	7.50	8.25	(a)	9.28	7.20	(a)	6.90	.....
22	7.60	7.40	7.50	8.40	9.20	9.00	7.40	(a)	6.90	.....
23	7.70	7.30	7.50	8.50	8.90	9.00	7.30	(a)	6.90	.....
24	7.60	7.40	7.50	8.60	9.00	8.95	6.80	(a)	7.00	.....
25	7.60	7.30	7.50	8.75	9.05	8.50	7.10	(a)	7.00	.....
26	7.60	7.30	7.80	8.80	9.00	8.40	7.20	(a)	7.00	.....
27	7.50	7.30	7.40	8.80	9.10	8.60	7.20	6.80	7.00	.....
28	7.50	7.30	8.20	8.75	9.20	8.70	7.10	6.90	7.00	.....
29	7.50	.....	7.90	8.55	9.25	8.60	7.20	6.85	7.00	.....
30	7.50	.....	7.80	8.65	9.45	8.10	7.20	6.90	7.00	.....
31	7.40	.....	7.80	.....	9.45	.....	.....	6.80	.....	.....

a No reading. Station discontinued October 14.

SNAKE RIVER AT MONTGOMERY FERRY, IDAHO.

This river passes from Wyoming into Idaho through a long and inaccessible canyon in the Snake River Range. Its north fork has its source in Henry Lake, in the Rocky Mountain divide, in the northeastern corner of Idaho, and flows southerly, entering the main stream near Idaho Falls. In the vicinity of Market Lake and Idaho Falls there is a large area of land under cultivation, irrigated from canals heading on Snake River and its smaller tributaries. Ten miles above the gaging station at Montgomery Ferry occurs a natural dam site, from which, as a starting point, surveys for canal lines have been run, covering the large extent of rolling country susceptible of irrigation on both sides of the river. This is a feasible project which up to the present time has not been utilized. Measurements at Montgomery Ferry show the amount of water available for irrigation purposes there, and also the amount that could be developed for power purposes at Shoshone Falls, about 45 miles below. The station, established August 5, 1895, is located at Montgomery Ferry, on the stage road from Minidoka to Albion. The gage is inclined and fastened to posts set in the ground. The bench mark is the head of a spike in the east post of the tool house, 1.2 feet above the ground and 52 feet west of the gage. Its elevation is 17.50 feet above gage datum. The letters "B. M." are marked in black paint on the post. The river is 800 feet wide at this section, with a hard gravel bottom not subject to change. When the

station was visited by N. S. Dils on October 14, 1899, a comparison was made of the gage rod with the bench mark, and it was found that the rod had moved to a considerable extent, due to the action of the quicksand on the inclined portion of the rod. The heights as recorded by the observer, as well as the discharge measurements, have been corrected. The rod is inclined from zero to 6.5 feet, and is vertical above this latter elevation. The lower portion is fastened at various intervals to posts driven into the ground. Owing to its considerable length the rod has not moved uniformly, and the corrections, therefore, are not in a constant ratio. From zero to 2.5 feet the correction to the gage heights is below one-tenth of a foot; from 2.6 to 3.7 feet, one-tenth of a foot should be added to the gage heights; from 3.8 to 4.9 feet, as the correction is below one-tenth of a foot it is negligible; from 5.0 feet to 6.5 feet the correction varies from 0.2 foot to 0.4 foot. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 335; 1897, Nineteenth Annual Report, Part IV, page 447; 1898, Twentieth Annual Report, Part IV, page 474. The following measurements of discharge were made by F. S. Shirley and N. S. Dils during 1899:

March 29, gage height, 3.04 feet; discharge, 5,688 second-feet.
May 23, gage height, 6.40 feet; discharge, 16,587 second-feet.
June 27, gage height, 10.70 feet; discharge, 35,718 second-feet.
July 29, gage height, 6.10 feet; discharge, 15,012 second-feet.
August 28, gage height, 3.68 feet; discharge, 7,292 second-feet.
October 14, gage height, 3.15 feet; discharge, 5,911 second-feet.

Daily gage height, in feet, of Snake River at Montgomery Ferry, Idaho, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	3.40	2.85	2.95	2.90	4.30	7.35	10.50	5.65	3.60	3.05
2	3.45	2.80	3.00	2.95	4.10	7.40	10.70	5.50	3.55	3.05
3	3.50	2.85	2.90	2.95	4.05	7.40	10.80	5.30	3.50	3.05
4	3.35	3.80	2.80	2.85	4.05	7.55	10.60	5.00	3.40	3.05
5	3.35	3.95	2.75	2.90	3.90	7.75	10.50	4.85	3.40	3.05
6	3.35	3.85	2.55	2.85	3.80	8.05	10.45	4.85	3.40	3.05
7	3.40	3.70	2.75	2.80	3.70	8.45	10.25	4.75	3.30	3.05
8	3.40	3.55	2.75	2.80	3.70	8.65	10.00	4.75	3.30	3.10
9	3.40	3.35	2.70	2.75	3.80	8.35	9.85	4.65	3.30	3.10
10	3.40	3.15	2.90	2.75	4.10	8.05	9.55	4.55	3.25	3.10
11	3.30	3.00	2.85	2.80	4.45	7.75	9.30	4.55	3.20	3.15
12	3.30	2.90	2.85	2.80	5.40	7.95	9.05	4.45	3.20	3.15
13	3.45	3.05	2.80	2.85	6.05	8.30	8.85	4.45	3.20	3.15
14	3.55	3.20	2.85	3.00	6.40	8.80	8.65	4.35	3.20	3.15
15	3.65	3.45	2.85	3.00	6.80	9.10	8.60	4.25	3.10	3.15
16	3.75	3.80	2.80	3.10	6.65	9.15	8.55	4.15	3.10	.....
17	3.90	3.75	2.85	3.35	6.60	8.80	8.45	4.15	3.10	.....
18	4.15	3.85	2.90	3.25	6.65	8.65	8.30	4.05	3.10	.....
19	4.25	2.95	2.90	3.55	6.50	8.85	8.10	3.95	3.00	.....
20	4.25	2.55	2.90	3.50	6.20	9.35	7.70	3.95	3.05	.....
21	4.50	2.75	2.90	3.50	6.20	9.95	7.45	3.85	3.10	.....
22	4.50	2.85	2.90	3.40	6.35	10.35	7.25	3.80	3.10	.....
23	4.50	2.80	2.85	3.30	6.40	10.75	7.05	3.80	3.10	.....
24	4.35	2.70	2.90	3.20	6.25	11.05	6.80	3.80	3.10	.....
25	4.35	2.70	2.90	3.30	6.10	11.20	6.75	3.80	3.10	.....
26	3.85	2.70	3.00	3.65	6.10	10.90	6.65	3.80	3.10	.....
27	3.20	2.45	3.00	3.95	6.45	10.55	6.50	3.80	3.10	.....
28	2.95	2.85	3.00	4.30	6.65	10.40	6.35	3.68	3.08	.....
29	2.75	.....	3.00	4.65	7.10	10.40	6.15	3.65	3.05	.....
30	2.70	.....	3.00	4.50	7.20	10.40	5.90	3.60	3.05	.....
31	3.00	.....	3.00	.....	7.25	.....	5.80	3.60	.....	.....

Station discontinued October 15.

LITTLE WOOD RIVER AT TOPONIS, IDAHO.

The headwater tributaries of this river drain a country adjoining those of Malade River on the east. It enters Snake River Desert and the lava area on its appearance from its mountainous basin. Irrigation is practiced along its course to such an extent that on the lower reaches the river is dry during the summer period. A measurement on this river at Shoshone, made by N. S. Dils on August 29, 1899, showed a discharge of 71 second-feet. At this time the gage at Toponis showed a discharge of 9 second-feet. The station was established June 2, 1896, and is located at the highway bridge one-half mile south of the railroad. The rod of the old wire gage was fastened to the floor of the bridge, but it was replaced March 28, 1899, by a vertical rod which is spiked to one of the supports of the bridge. The bench mark is a spike opposite the 8-foot mark on the bridge support to which the rod is fastened. During the flood periods two side channels have to be measured, as well as the main stream. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 337; 1897, Nineteenth Annual Report, Part IV, page 449. The following discharge measurements were made by F. S. Shirley and N. S. Dils during 1899:

March 28, gage height, 4.40 feet; discharge, 164 second-feet.
March 28, gage height;[1] discharge, 25 second-feet.
May 25, gage height, 1.50 feet; discharge, 0.1 second-feet.
June 24, gage height, 2 feet; discharge, 11 second-feet.

Daily gage height, in feet, of Little Wood River at Toponis, Idaho, for 1899.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	4.50	4.25	3.05	1.00	1.60	1.30	1.80	2.50
2	5.60	4.25	3.15	.90	1.70	1.20	1.80	2.60
3	5.60	4.20	3.05	.90	1.70	1.10	1.80	2.60
4	5.40	4.40	3.05	1.00	1.70	1.00	2.25	2.70
5	5.30	4.40	2.90	1.20	1.75	1.00	2.25	2.90
6	5.20	4.50	2.85	1.75	1.70	1.70	2.00	2.90
7	5.00	4.40	2.65	1.60	1.70	1.50	1.80	2.90
8	5.00	4.30	2.65	1.70	1.60	1.50	1.70	2.90
9	4.80	4.40	2.60	1.70	1.70	1.30	1.70	3.00
10	4.85	4.25	2.60	1.65	1.70	1.50	1.70	3.00
11	4.80	4.10	2.50	1.70	1.85	1.70	1.60	3.00
12	5.00	4.10	2.40	1.70	1.80	1.75	1.60	3.00
13	4.60	4.00	2.25	1.60	1.80	1.75	1.60	3.10
14	4.50	3.90	2.05	1.60	1.75	1.75	1.70	3.10
15	4.50	3.80	2.00	1.50	1.70	1.75	1.70	.....
16	4.30	3.80	1.80	1.45	1.70	1.75	1.70	.....
17	4.00	3.75	1.70	1.35	1.70	1.75	1.50	.....
18	3.90	3.70	1.30	1.30	1.75	1.75	1.50	.....
19	4.00	3.70	1.50	1.25	1.75	1.80	1.60	.....
20	3.80	3.70	1.50	1.10	1.70	1.80	1.70	.....
21	3.80	3.70	1.50	1.00	1.70	1.75	1.70	.....
22	3.85	3.50	1.50	1.90	1.55	1.75	1.60	.....
23	3.85	3.50	1.50	2.00	1.60	1.90	1.60	.....
24	3.90	3.50	1.50	1.95	1.70	2.10	2.10	.....
25	4.00	3.30	1.50	1.65	1.60	2.00	2.30	.....
26	4.20	3.20	1.50	1.65	1.70	1.80	2.40	.....
27	4.35	3.25	1.50	1.70	1.70	1.80	2.50	.....
28	4.45	3.25	1.40	1.70	1.70	1.80	2.50	.....
29	4.20	3.20	1.40	1.65	1.75	1.80	2.50	.....
30	4.10	2.95	1.20	1.60	1.70	1.80	2.50	.....
31	4.10	.....	1.00	.....	1.50	1.80	.....	.....

Station discontinued October 14.

[1] Measurement made on a slough, 500 feet south of railroad, into which water had been diverted from Little Wood River for irrigation purposes.

MALADE RIVER AT TOPONIS, IDAHO.

Malade River, or Big Wood, as it is sometimes called, has its source in the high, mountainous area north of Ketchum, Idaho, and flows southerly. Below the mouth of its tributary, Camas Creek, which enters from the west, the main stream enters a broken lava country in which there is no surface addition to its flow, the rainfall percolating down through the soil of the lava beds. Considerable irrigation is practiced within its basin, and a number of canal diversions are made above the station. Recourse must be had to storage on this river for further increase of its agricultural lands. The station, established June 2, 1896, is located at the wagon bridge one-half mile north of the town of Toponis. The gage is vertical and is spiked to the south face of one of the bridge piers. The bench mark is the head of a spike driven into the pier opposite the 12-foot mark. The channel is straight for some distance above and below the station, and the current is moderately swift. The banks are high and not liable to overflow. The results of measurements are found as follows: 1896, Eighteenth Annual Report, Part IV, page 337; 1897, Nineteenth Annual Report, Part IV, page 449; 1898, Twentieth Annual Report, Part IV, page 477. The following measurements of discharge were made by F. S. Shirley and N. S. Dils during 1899:

March 28, gage height, 2.40 feet; discharge, 42 second-feet.
May 25, gage height, 3.80 feet; discharge, 523 second-feet.
June 24, gage height, 5 feet; discharge, 1,356 second-feet.
July 27, gage height, 2.80 feet; discharge, 125 second-feet.

Daily gage height, in feet, of Malade River at Toponis, Idaho, for 1899.

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	.....	2.00	2.60	3.80	4.20	4.60	2.50	1.20	2.00
2	.....	2.80	2.85	3.80	4.25	4.60	2.40	1.20	1.95
3	.....	2.45	2.75	3.80	4.25	4.60	2.80	1.20	1.95
4	.....	2.35	2.80	3.75	4.40	4.55	2.80	1.20	1.90
5	.....	2.20	2.70	3.80	4.55	4.50	2.20	1.20	1.90
6	.....	2.30	2.65	3.90	4.60	4.10	2.10	1.20	1.90
7	.....	2.45	2.75	3.90	4.60	3.90	2.00	1.90	1.85
8	.....	2.50	2.75	3.90	4.60	3.80	2.00	1.90	1.85
9	.....	2.55	2.90	3.70	4.40	3.70	2.00	1.90	1.90
10	.....	2.30	3.00	4.05	4.10	3.65	2.00	1.80	2.00
11	.....	2.05	3.00	4.30	4.20	3.65	1.90	1.70	2.00
12	.....	2.00	3.60	4.65	4.40	3.60	2.10	1.70	2.00
13	.....	2.00	4.10	5.00	4.40	3.55	2.10	1.70	2.00
14	.....	1.95	4.60	4.80	4.40	3.65	2.00	1.65	2.00
15	.....	1.70	4.75	4.60	4.40	3.60	2.00	1.60	.....
16	.....	1.60	5.10	4.70	4.40	3.45	2.00	1.60	.....
17	.....	2.60	5.55	4.50	4.50	3.30	2.00	1.60	.....
18	3.30	2.45	5.45	4.30	4.85	3.20	2.00	1.70	.....
19	2.90	2.45	6.20	4.20	4.70	3.10	1.90	1.80	.....
20	3.00	2.45	6.10	4.10	4.90	3.00	1.90	1.90	.....
21	2.60	2.45	5.10	4.00	5.20	3.00	1.80	1.80	.....
22	2.50	2.10	5.00	3.90	5.40	2.95	1.70	1.90	.....
23	2.40	2.40	5.00	3.90	5.05	2.90	1.50	1.90	.....
24	2.00	2.60	5.00	3.80	4.90	2.90	1.30	1.80	.....
25	2.10	3.70	5.00	3.80	4.90	2.80	1.30	1.90	.....
26	2.10	2.95	5.00	3.80	4.80	2.70	1.30	2.00	.....
27	2.05	2.50	5.40	4.00	4.75	2.70	1.55	2.00	.....
28	2.10	2.40	4.90	4.00	4.55	2.65	1.55	2.00	.....
29	.....	2.50	4.40	4.15	4.60	2.65	1.40	2.00	.....
30	.....	2.50	4.00	4.35	4.60	2.55	1.30	2.00	.....
31	.....	2.50	.....	4.30	.....	2.50	1.20	.....	.....

Closed for winter October 14.

MALADE RIVER AT BLISS, IDAHO.

There is a large increase in the discharge of this river below the mouth of Little Wood River, which is evidently due to the entrance of springs from the lava desert. Surveys have recently been completed in order to determine the practicability of carrying water from lower Malade River across Snake River for placer mining and irrigation purposes. In order to determine the increase by the underground flow, and the amount available for future hydraulic developments, a station was established by Frank S. Shirley March 27, 1899. The station is located at the wagon bridge 8 miles southwest from the railroad station at Bliss, and is reached by stage from the latter place. The rod is vertical and consists of a 2 by 4 inch timber spiked to the bridge abutment. The bench mark is two nails driven into the east abutment opposite the 12-foot mark. The locality is a good one for measurements, with high banks not subject to overflow, and with a rocky bed not liable to change. The following measurements of discharge were made by F. S. Shirley and N. S. Dils in 1899:

March 27, gage height, 2.50 feet; discharge, 1,345 second-feet.
May 26, gage height, 2.70 feet; discharge, 1,736 second-feet.
June 23, gage height, 3.50 feet; discharge, 2,878 second-feet.
July 26, gage height, 2.30 feet; discharge, 1,203 second-feet.
September 23, gage height, 2.15 feet; discharge, 1,095 second-feet.

Daily gage height, in feet, of Malade River at Bliss, Idaho, for 1899.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	.....	2.40	2.90	2.90	3.00	2.20	2.15	2.20
2	.....	2.70	2.80	2.90	3.00	2.20	2.15	2.20
3	.....	2.70	2.80	2.90	3.00	2.20	2.15	2.20
4	.....	2.60	2.70	2.90	3.00	2.20	2.15	2.20
5	.....	2.50	2.70	2.90	3.00	2.20	2.15	2.20
6	.....	2.60	2.60	3.00	2.90	2.15	2.15	2.20
7	.....	2.50	2.50	3.00	2.80	2.15	2.15	2.20
8	.....	2.50	2.50	3.00	2.70	2.15	2.15	2.20
9	.....	2.90	2.50	2.90	2.70	2.15	2.15	2.20
10	.....	2.90	2.70	2.90	2.70	2.15	2.15	2.20
11	.....	2.90	2.90	2.90	2.70	2.15	2.15	2.20
12	.....	3.00	3.10	3.00	2.60	2.15	2.15	2.20
13	.....	3.00	3.50	3.00	2.60	2.15	2.15	2.20
14	.....	3.10	3.30	3.10	2.60	2.15	2.15	2.20
15	.....	3.30	3.30	3.00	2.60	2.15	2.15	.....
16	.....	(a)	3.00	2.90	2.50	2.15	2.15	.....
17	.....	3.50	3.00	2.90	2.50	2.15	2.15	.....
18	.....	3.80	3.00	3.00	2.50	2.15	2.15	.....
19	.....	3.90	2.90	3.30	2.40	2.15	2.15	.....
20	.....	4.00	2.80	3.50	2.40	2.15	2.15	.....
21	.....	3.50	(a)	3.80	2.30	2.15	2.15	.....
22	.....	3.30	2.80	3.70	2.30	2.15	2.15	.....
23	.....	(a)	2.70	3.50	2.30	2.15	2.15	.....
24	.....	3.40	2.70	3.40	2.30	2.15	2.15	.....
25	.....	3.60	2.60	3.30	2.30	2.15	2.15	.....
26	.....	3.50	2.70	3.30	2.30	2.15	2.15	.....
27	2.50	3.50	2.80	3.20	2.30	2.15	2.15	.....
28	2.40	3.40	2.80	3.20	2.20	2.15	2.20	.....
29	2.30	3.10	2.80	3.10	2.20	2.15	2.20	.....
30	2.30	3.00	2.90	3.10	2.20	2.15	2.20	.....
31	2.40	.....	2.90	.....	2.20	2.15	.....	.....

a No reading.

Closed for winter October 14.

BRUNEAU RIVER AT GRANDVIEW, IDAHO.

This river has its source in northern Nevada, and flows in a general northerly course, entering Snake River in Owyhee County. Its basin is of a rolling character and is devoted to stock raising. Systematic measurements on this river have been maintained by Mr. Andrew J. Wiley, for the Owyhee Land and Irrigation Company, immediately below the headworks of their canal system, 10 miles east of Grandview, Idaho. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 340; 1897, Nineteenth Annual Report, Part IV, page 450; 1898, Twentieth Annual Report, Part IV, page 482. No measurements were made at this station during 1899.

Daily gage height, in feet, of Bruneau River at Grandview, Idaho, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.50	1.80	1.70	2.40	3.20	3.95	3.75	1.90	1.45	1.45	1.70	1.70
2	1.50	1.80	1.70	2.50	3.10	4.00	3.70	1.85	1.40	1.50	1.70	1.70
3	1.50	1.70	1.90	2.50	3.00	4.25	3.60	1.80	1.45	1.50	1.70	1.65
4	1.50	1.60	1.90	2.50	2.90	4.65	3.50	1.80	1.40	1.50	1.70	1.65
5	1.50	1.30	1.70	2.50	2.80	4.65	3.45	1.75	1.40	1.50	1.70	1.65
6	1.55	1.25	1.75	2.60	2.80	7.85	3.30	1.85	1.40	1.50	1.75	1.60
7	1.55	1.20	1.75	2.70	2.95	4.95	3.25	1.90	1.40	1.50	1.75	1.60
8	1.55	1.20	1.70	2.80	3.30	4.80	3.20	1.80	1.40	1.55	1.75	1.65
9	1.60	1.50	2.30	3.10	3.50	4.75	3.15	1.80	1.40	1.55	1.70	1.65
10	1.60	1.65	2.50	3.40	4.00	4.70	3.00	1.85	1.40	1.55	1.70	1.65
11	1.60	2.50	2.30	4.50	4.65	4.75	3.00	1.80	1.45	1.50	1.75	1.65
12	1.55	2.30	2.00	4.50	4.85	4.90	2.90	1.80	1.45	1.55	1.75	1.65
13	1.55	1.90	1.90	5.00	5.00	5.15	2.80	1.75	1.40	1.55	1.75	1.70
14	1.55	1.80	1.90	5.20	5.00	5.15	2.80	1.75	1.45	1.60	1.70	1.70
15	1.60	1.80	1.80	5.00	4.80	4.80	2.75	1.70	1.45	1.65	1.80	1.65
16	3.90	1.80	1.80	4.80	4.55	4.60	2.70	1.65	1.45	1.65	1.75	1.65
17	2.55	1.80	1.85	5.00	4.40	4.65	2.60	1.60	1.40	1.70	1.70	1.70
18	2.30	1.75	1.85	5.00	4.00	4.75	2.55	1.65	1.40	1.70	1.70	1.70
19	2.30	1.70	2.00	4.40	3.80	5.00	2.50	1.65	1.45	1.70	1.70	1.65
20	2.00	1.75	1.95	4.20	3.70	5.00	2.45	1.65	1.45	1.70	1.70	1.60
21	1.85	2.30	1.90	3.90	3.55	5.20	2.40	1.60	1.45	1.75	1.70	1.55
22	1.90	2.40	1.90	4.00	3.45	5.00	2.35	1.65	1.45	1.75	1.70	1.55
23	1.80	2.00	1.90	4.40	3.40	4.60	2.25	1.60	1.45	1.70	1.70	1.50
24	1.80	1.80	1.85	4.40	3.50	4.30	2.20	1.65	1.45	1.70	1.70	1.50
25	1.75	1.80	3.00	4.30	3.70	4.20	2.20	1.60	1.45	1.70	1.70	1.50
26	1.80	1.75	4.40	4.30	3.95	4.25	2.10	1.60	1.45	1.75	1.70	1.50
27	1.80	1.70	3.40	3.80	4.00	4.10	2.05	1.60	1.50	1.75	1.70	1.55
28	1.80	1.70	3.00	3.70	3.85	4.00	2.00	1.55	1.50	1.75	1.70	1.50
29	1.80	.....	2.80	3.50	3.90	3.80	2.00	1.55	1.50	1.75	1.70	1.55
30	1.80	.....	2.60	3.30	3.85	3.75	1.95	1.50	1.50	1.70	1.70	1.60
31	1.80	.....	2.50	.....	4.15	.....	1.90	1.50	.....	1.70	.....	1.65

BOISE RIVER AT BOISE, IDAHO.

This river drains a mountainous and well-wooded country in Elmore County, Idaho. The effects of the forests are shown in the high flow that is maintained throughout the summer season, in contrast to the discharge of Weiser River farther to the west, which drains a more barren country. Below the gaging station, which is located in the canyon, a large number of canals divert water to irrigate lands in Boise Valley. These diversions are now carried to such an extent that frequent complaint of the scarcity of water is heard. It is estimated that 13,000 acres of land are irrigated by canals from Boise River. The station, established December 15, 1894, is located about 9 miles

above Boise, Idaho, at the mouth of the canyon. June 17, 1897, the present rod was placed, consisting of an inclined timber firmly attached to a cottonwood tree. Bench mark No. 1 is a 20-penny spike in the upstream face of the 6 by 8 cable support, about 2 feet above the ground, and is at an elevation of 15 feet above gage datum. Bench mark No. 2 consists of two spikes in the same post, at a height of 14 feet above gage datum. The equipment consists of a cable and car. At ordinary stages the channel is straight both above and below the station. The banks are high and not liable to overflow. About 300 feet below the cable is a gravel bar reducing the width of the river in low water to about one-third of the channel, and forcing the entire flow against the south bank. The channel is liable to change during extreme high floods. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 342; 1897, Nineteenth Annual Report, Part IV, page 453; 1898, Twentieth Annual Report, Part IV, page 483. The following discharge measurements were made by F. S. Shirley and N. S. Dils during 1899:

Discharge measurements of Boise River at Boise, Idaho.

1899.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
March 24	1.90	1,846	July 11	4.30	7,394
April 4	2.70	3,418	August 2	2.00	2,054
May 16	5.10	9,927	August 26	1.55	1,583
May 28	5.10	10,711	September 14	1.20	1,105

Daily gage height, in feet, of Boise River at Boise, Idaho, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.30	1.30	1.60	2.40	3.90	5.10	5.40	2.20	1.40	1.10	1.40	2.00
2	2.30	1.30	1.60	2.50	3.60	5.20	5.10	2.00	1.40	1.10	1.40	1.70
3	2.30	1.20	1.60	2.50	3.50	5.80	5.10	2.00	1.40	1.10	1.30	1.55
4	2.30	1.20	1.60	2.60	3.40	6.10	5.00	2.00	1.40	1.10	1.40	1.35
5	2.30	1.30	1.50	2.90	3.60	6.10	4.70	2.00	1.35	1.10	1.40	1.30
6	2.40	1.30	1.50	2.90	3.80	5.40	4.50	2.00	1.30	1.10	1.40	1.30
7	2.40	1.20	1.50	2.90	4.80	5.20	4.45	2.10	1.30	1.10	1.40	1.40
8	2.40	1.40	1.50	3.30	5.00	5.20	4.60	2.20	1.30	1.15	1.50	1.40
9	2.40	1.60	1.40	3.70	6.00	5.00	4.45	2.20	1.30	1.15	1.45	1.50
10	2.40	1.90	1.40	4.20	7.50	5.10	4.40	2.00	1.30	1.15	1.40	1.60
11	2.40	1.60	1.40	4.40	7.00	5.50	4.30	1.90	1.30	1.15	1.5o	1.60
12	2.40	1.60	1.45	4.60	6.20	6.10	4.20	1.90	1.20	1.20	1.75	1.50
13	2.40	1.60	1.45	4.55	6.00	5.10	4.10	1.75	1.20	1.20	1.80	1.50
14	2.40	1.40	1.40	4.35	5.80	5.40	3.90	1.70	1.20	1.25	1.70	1.50
15	2.50	1.50	1.40	4.30	5.40	5.20	3.70	1.70	1.30	1.25	1.60	1.40
16	2.50	1.50	1.40	5.10	5.10	5.40	3.50	1.70	1.35	1.25	1.70	1.40
17	2.50	1.60	1.40	4.65	5.00	6.10	3.40	1.70	1.25	1.30	1.65	1.60
18	2.50	1.60	1.60	4.70	4.80	6.70	3.30	1.60	1.20	1.50	1.60	1.60
19	2.50	1.60	1.90	4.20	4.40	7.00	3.25	1.55	1.20	1.85	1.60	1.80
20	2.50	1.60	2.00	4.10	4.30	7.40	3.10	1.60	1.20	2.00	1.60	1.80
21	2.50	1.50	2.00	4.10	4.30	6.40	3.10	1.70	1.20	2.20	1.50	1.60
22	2.50	1.50	1.80	4.50	1.60	5.40	2.90	1.80	1.15	2.00	1.50	1.60
23	2.40	1.40	1.80	5.30	4.80	5.20	2.80	1.80	1.15	1.90	1.50	1.60
24	2.40	1.30	1.90	5.90	5.00	5.60	2.50	1.70	1.15	1.80	1.40	1.80
25	2.40	1.30	2.90	5.40	5.30	5.60	2.50	1.60	1.15	1.60	1.40	1.60
26	2.40	1.40	2.05	5.50	5.00	5.40	2.40	1.50	1.10	1.50	1.40	1.60
27	2.00	1.50	2.30	4.80	4.80	5.20	2.30	1:45	1.10	1.50	1.40	1.60
28	1.60	1.50	2.40	4.50	5.15	5.40	2.30	1.30	1.10	1.50	1.50	1.80
29	1.40	.....	2.40	4.30	5.20	5.65	2.20	1.30	1.10	1.50	1.80	1.80
30	1.30	.....	2.40	4.10	5.40	5.40	2.25	1.20	1.10	1.50	2.00	1.60
31	1.30	.....	2.30	.....	5.30	.....	2.20	1.20	.....	1.40	.....	1.80

A series of measurements of Boise River and canals taking water from it were made by N. S. Dils September 12 to 16, 1899. The route followed was similar to that taken by Cyrus C. Babb, as noted in the Twentieth Annual, Part IV, page 484. The following list gives the localities, together with the results obtained:

Discharge measurements of canals in Boise Valley, Idaho.

1899.

Date.	Canal.	Locality.	Discharge.
			Second-feet.
Sept. 12	Sebree	Near head	198
Sept. 12	Seitenberg slough	Near head	47
Sept. 12	Boise River	300 feet below Caldwell bridge.	439
Sept. 12	Riverside canal	Near head	10
Sept. 12	Waste east of Caldwell	Near river	7
Sept. 12	Waste Tenmile	Near river	35
Sept. 12	Strahorn canal	Near head	49
Sept. 12	Four small wastes	Near river	2
Sept. 12	Boise River	Star bridge	486
Sept. 13	Waste south of Star	Near river	22
Sept. 13	Waste south of Star bridge	Near river	5
Sept. 13	Eureka canal	Near head	47
Sept. 13	Phyllis canal	Near head; dry	----------
Sept. 13	Settlers canal	Near head	52
Sept. 13	McCarty canal	Near head	11
Sept. 13	Davis canal	Near head	20
Sept. 13	Waste Rossi	Near river	43
Sept. 13	Payne canal	Near head	5
Sept. 13	Rossi canal	Below waste gate	51
Sept. 14	Perault canal	Below mill	25
Sept. 14	Ellis canal	Near head	3
Sept. 14	Perault canal [1]	Below waste gate	88
Sept. 14	Boise River	United States Geological Survey gaging station.	1,105
Sept. 14	Costin canal	Near head	3
Sept. 14	Ridenbaugh canal	Near head	356
Sept. 14	Jacobs canal	Near head	43
Sept. 15	Waste Carline	Main street bridge	29
Sept. 15	Farmers Union	Near head	47
Sept. 15	Waste	One-half mile below Soldiers' Home.	7
Sept. 15	Waste	Two miles below Soldiers' Home.	7
Sept. 15	Dry Creek canal	Near head	23
Sept. 15	Union canal	Near head; dry	----------
Sept. 15	Ballentine canal	Near head; dry	----------
Sept. 15	Waste Dry Creek	Near river	2
Sept. 15	Waste	Near head; Cassiday	3
Sept. 15	Cassiday canal	Near head; dry	----------
Sept. 15	Middleton canal	Near head	84
Sept. 15	Swallew & McDowell	Near head	8
Sept. 16	Catlin & Macey	Eagle Island	14
Sept. 16	Aitken	Eagle Island	7
Sept. 16	Conway & Aitken	Eagle Island	7
Sept. 16	Davis & Hart	Eagle Island	7
Sept. 16	Middleton Mill slough	Near head	14
Sept. 16	Pioneer canal	Near head	3
Sept. 16	Middleton Water Company	Near head	32
Sept. 16	Waste West Middleton	Willow Creek	13
Sept. 16	Waste West Middleton	Near river	1
Sept. 16	Waste East Middleton	Near river	17

[1] Perault above mill feeds Perault below mill and waste flows into Ellis canal.

SUMMARY.

	Second-feet.
In river at Star bridge	486
Taken out by canals above Star	891
	1,377
In river above canals	1,105
Return water above Star	91
	1,196
Gain	181
In river at Caldwell	439
Taken out by canals	1,227
	1,666
In river above canals	1,105
Return water	192
	1,297
Gain 34 miles	369
Gain per mile, 1899	11
Gain per mile, 1898	8
Increase	3

PAYETTE RIVER AT PAYETTE, IDAHO.

This river drains a well-wooded mountainous area similar to the basin of the Boise. The effect of the forest is shown in the well-sustained summer flow. Systematic measurements were formerly made on this river, but owing to the excess of water above the needs of the irrigators, this station is not now maintained. September 10, 1899, a measurement at Payette by N. S. Dils showed a discharge of 1,677 second-feet.

WEISER RIVER AT WEISER, IDAHO.

The drainage basin of this river is mountainous and rocky, in contrast to the well-wooded areas of the Boise and Payette basins, and the effect is shown in the high flood discharges and low summer flow. A number of small ditches utilize considerable water from this river, but the principal canal is the Galloway canal, which irrigates lands north of Weiser. Above this canal is a bench country susceptible of cultivation if water could be brought to it. The gaging station, established December 6, 1894, is located in the canyon of the river, about 10 miles from Weiser. The gage rod which was set in 1898 was covered during the process of grading for the roadbed of the new Pacific and Idaho Northern railroad, which is a line intended to run from Weiser to the mining country in the mountainous district to the north. The new gage, located on October 31, 1899, 100 feet

above the old one, is inclined and bolted to a rock bluff; 1.15 feet along the gage equals one foot in elevation. The bench mark consists of a cross cut in the top of the lava rim rock above the gage, and is at an elevation of 12.90 feet. The elevation of the zero of the gage taken from the levels of the railroad is 2,191.34 feet above sea level. Discharge measurements are made from a cable and car about 300 feet below the gage. Both banks are high and not liable to overflow. The bed of the river is of gravel and not susceptible to change. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 353; 1897, Nineteenth Annual Report, Part IV, page 457; 1898, Twentieth Annual Report, Part IV, page 488. The following discharge measurements were made by F. S. Shirley and N. S. Dils in 1899:

March 22, gage height, 3.80 feet; discharge, 2,822 second-feet.
April 16, gage height, 4.70 feet; discharge, 3,831 second-feet.
May 18, gage height, 4.20 feet; discharge, 3,092 second-feet.
May 29, gage height, 4 feet; discharge, 2,839 second-feet.
July 8, gage height, 2.40 feet; discharge, 1,195 second-feet.
September 9, gage height, 0.75 foot; discharge, 145 second-feet.

Daily gage height, in feet, of Weiser River at Weiser, Idaho, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.00	1.60	2.10	5.00	3.80	4.10	3.20	1.20	0.80	0.50	1.10	2.40
2	2.00	1.50	2.20	5.00	3.40	4.30	3.00	1.20	.80	.50	1.10	2.30
3	2.00	1.60	2.30	5.10	3.20	4.70	2.90	1.20	.80	.50	1.10	2.20
4	2.00	1.80	2.40	5.00	3.05	4.90	2.80	1.10	.80	.50	1.10	2.10
5	2.00	1.90	2.30	5.00	3.00	4.60	2.70	1.10	.80	.50	1.10	2.00
6	2.00	2.00	2.30	5.10	3.15	4.30	2.60	1.10	.80	.50	1.10	.....
7	2.00	1.80	2.40	5.00	3.70	4.00	2.50	1.10	.80	.50	1.10	.....
8	2.00	1.70	2.50	4.90	4.40	3.80	2.40	1.00	.80	.50	1.50	.....
9	2.00	1.60	2.60	5.05	4.90	3.80	2.30	1.00	.80	.50	1.60	.....
10	2.00	1.50	2.70	5.15	5.15	3.90	2.20	1.00	.80	.50	1.70	.....
11	2.00	1.40	2.80	5.10	5.30	4.00	2.20	1.00	.80	.60	1.90	.....
12	2.00	1.40	2.60	5.20	5.20	4.10	2.10	1.00	.70	.60	2.00	.....
13	2.00	1.40	2.60	5.60	5.20	4.20	2.10	.90	.70	.60	2.00	.....
14	2.00	1.40	2.70	5.30	4.70	4.20	2.00	.90	.70	.60	1.90	.....
15	2.00	1.40	2.80	4.70	4.40	4.30	2.00	.90	.70	.60	1.80	.....
16	2.10	1.40	3.00	4.70	4.00	4.30	2.90	.90	.70	.80	1.70	.....
17	2.20	1.40	4.70	4.90	3.80	4.30	2.90	.90	.70	.80	1.60	.....
18	2.40	1.45	4.80	4.60	3.70	4.40	2.80	.90	.70	.90	1.60	.....
19	2.60	1.50	4.60	4.30	3.60	4.60	1.80	.80	.70	1.00	1.60	.....
20	3.60	1.65	4.50	4.10	3.60	4.60	1.70	.80	.70	1.20	1.70	.....
21	3.90	1.70	4.20	4.00	3.60	4.50	1.70	.80	.60	1.30	1.70	.....
22	4.40	1.70	3.80	4.30	3.60	4.10	1.60	.80	.60	1.40	1.80	.....
23	5.00	1.70	3.70	4.20	3.70	3.80	1.60	.80	.60	1.40	1.90	.....
24	5.60	1.60	6.35	4.00	4.00	3.80	1.50	.80	.60	1.30	2.00	.....
25	5.00	1.60	6.40	4.60	4.30	3.70	1.50	.90	.60	1.30	2.50	.....
26	8.60	1.70	6.30	4.60	4.30	3.70	1.40	.90	.60	1.20	2.80	.....
27	3.00	1.80	6.80	4.00	4.20	3.60	1.40	.90	.50	1.20	3.00	.....
28	2.60	1.90	4.90	3.80	4.20	3.50	1.40	.80	.50	1.20	4.10	.....
29	2.20	.....	4.80	3.80	4.00	3.40	1.30	.80	.50	1.10	4.20	.....
30	2.20	.....	5.20	3.70	4.00	3.30	1.30	.80	.50	1.10	4.30	.....
31	1.70	.....	5.00	.....	4.05	.....	1.30	.80	.....	1.10	.....	.....

River frozen; closed for winter December 5.

PALOUSE RIVER AT HOOPER, WASHINGTON.

The headwater tributaries of this river have their sources in western Idaho, adjoining the headwater streams of Potlatch River, a tributary of Clearwater River. After passing into Washington they

unite to form the main Palouse, which has a general southwesterly direction, passing through a rolling country. Six miles below Hooper, Washington, the river bends suddenly southward and enters its canyon, through which it continues until its junction with Snake River. For some distance above Hooper the river consists of a succession of deep pools, from 10 to 15 feet in depth, connected by short riffles. Its valley is about one-half mile in width and bordered with basaltic cliffs approximately 300 feet in height. A short distance above the mouth of the river are the Palouse Falls, which are approximately 130 feet in height.

The measurements of Palouse River are of value in showing the amount of water that could be utilized for irrigation on the lands of Washtucna Valley and in the section north of Pasco. The gaging station, established September 9, 1897, is located near Hooper, opposite the water tank of the railroad company. It is about 3 miles above the mouth of Cow Creek and 2 miles below the head of the ditch of the Palouse Irrigation Company, which carries, when full, 25 second-feet. The rod is inclined and fastened to posts driven into the right bank. The bench mark is a point of rock, marked with red paint, on the left bank of the river, opposite the gage, and its elevation is 7.60 feet above gage datum. The channel is gravel and not liable to change. The left bank is high and can not overflow, but the right bank overflows at extreme high water. The results of measurements may be found as follows: 1897, Nineteenth Annual Report, Part IV, page 460; 1898, Twentieth Annual Report, Part IV, page 489. No measurements of discharge were made at this point in 1899.

Daily gage height, in feet, of Palouse River at Hooper, Washington, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.70	5.30	4.70	5.10	5.40	3.45	2.25	1.60	1.60	1.50	2.10	4.40
2	2.60	5.20	6.45	5.00	5.40	3.35	2.30	1.60	1.60	1.50	2.05	5.00
3	2.60	4.70	6.30	5.30	5.25	3.30	2.35	1.55	1.60	1.50	2.05	5.50
4	2.60	4.30	5.90	5.30	4.90	3.25	2.30	1.55	1.60	1.50	2.00	5.80
5	2.55	4.00	5.40	5.45	4.50	3.30	2.25	1.55	1.60	1.50	1.95	5.50
6	2.30	4.00	5.25	5.30	4.30	3.35	2.25	1.50	1.65	1.50	1.95	4.70
7	2.10	3.90	5.10	5.20	4.20	3.40	2.20	1.50	1.60	1.50	1.95	4.30
8	2.30	3.80	5.45	5.20	4.40	3.20	2.20	1.45	1.60	1.50	1.90	4.10
9	2.45	3.80	5.80	5.60	4.90	3.10	2.15	1.45	1.60	1.50	1.90	3.90
10	2.50	3.90	6.40	5.85	5.65	3.00	2.10	1.45	1.65	1.50	1.95	3.90
11	2.55	4.20	6.50	6.35	5.85	2.80	1.95	1.40	1.70	1.50	1.95	3.90
12	2.55	3.90	5.90	6.85	5.90	2.70	1.80	1.40	1.70	1.50	1.95	3.90
13	2.50	3.90	5.70	7.65	5.55	2.70	1.75	1.40	1.65	1.50	1.95	3.80
14	2.50	3.90	5.45	9.65	5.20	2.80	1.75	1.40	1.65	1.50	2.00	4.05
15	2.80	5.15	5.15	8.75	4.90	2.80	1.70	1.40	1.65	1.50	2.00	3.90
16	4.10	7.30	5.00	7.30	4.40	2.65	1.70	1.45	1.65	1.50	2.05	3.65
17	3.90	8.10	4.80	6.50	4.15	2.55	1.95	1.45	1.60	1.55	2.10	3.50
18	5.60	8.15	5.40	6.60	4.00	2.45	1.90	1.40	1.60	1.60	2.15	3.40
19	6.40	8.00	5.10	7.00	4.05	2.35	1.80	1.50	1.65	1.65	2.15	3.30
20	6.45	7.90	4.90	6.70	4.00	2.35	1.65	1.60	1.70	1.80	2.15	3.10
21	6.55	7.50	4.85	6.40	3.90	2.25	1.60	1.55	1.65	2.05	2.20	3.35
22	7.55	7.00	5.25	5.80	3.85	2.25	1.60	1.65	1.60	2.30	3.15	3.40
23	8.00	6.50	5.00	5.65	3.80	2.25	1.55	1.65	1.60	2.30	3.10	3.60
24	8.50	5.30	5.15	5.80	3.65	2.20	1.50	1.60	1.60	2.60	2.90	4.70
25	7.70	5.00	5.70	5.60	3.70	2.20	1.40	1.60	1.60	2.40	2.90	5.00
26	7.10	4.70	5.45	5.40	3.85	2.20	1.45	1.55	1.55	2.30	2.70	5.20
27	6.50	4.50	5.10	5.35	4.00	2.15	1.50	1.50	1.55	2.30	2.60	5.00
28	6.30	4.60	4.80	6.00	4.00	2.15	1.60	1.55	1.55	2.25	2.70	4.80
29	6.05	.....	4.70	6.20	3.80	2.15	1.60	1.60	1.55	2.20	2.85	4.60
30	5.90	.....	4.80	5.90	3.60	2.20	1.60	1.65	1.50	2.10	3.60	4.40
31	5.70	.....	5.00	.....	3.45	.....	1.60	1.65	.....	2.10	.....	4.10

BLACKFOOT RIVER AT BONNER, MONTANA.

This river has its source on the western slope of the main divide of the Rocky Mountains in Deerlodge County. Its drainage basin is mountainous and well wooded, and little cultivation is possible within the area. The Clearwater Lakes near the head serve as a reservoir, giving the stream a relatively constant flow. The principal industrial applications of the river are found near its mouth, where the water can be used for power purposes as well as for the irrigation of the adjacent lands. Measurements at this point are affected to a certain extent by the dam of the Big Blackfoot Milling Company, which is located about 1,000 yards above the station, and which furnishes water for the mills and electric-power stations. The opening and closing of the flood gates of the dam cause abrupt changes in the recorded gage heights. The station, established July 7, 1898, is located at the wagon bridge one-half mile west of Bonner and 6 miles east of Missoula. The rod of the wire gage is fastened to the upper side of the bridge. Bench mark No. 1, established by the Topographic Division of the United States Geological Survey, is a cross cut by a chisel on the top and northeast corner of the northeast buttress of the Northern Pacific railway bridge over Big Blackfoot River near Bonner, and is at an elevation above sea of 3,290.298 feet. Bench mark No. 2 is a regulation United States Geological Survey iron post on the east side of the river, 10 yards south of the highway and 20 yards north of Mr. McCormick's house, outside of dooryard fence, and at an elevation of 3,246.038 feet. The elevation of the axle of the pulley of the wire gage is 3,251.678 feet. The length of the wire gage is 22.75 feet. This gage was verified June 10, 1899, and September 8, 1899, when a stretch of the cable or a movement of the index of 0.55 foot was found to have occurred. The results of measurements for 1898 may be found in the Twentieth Annual Report, Part IV, page 491. The following measurements of discharge for 1899 were made under the direction of F. D. Smith:

Discharge measurements of Blackfoot River at Bonner, Montana.

1899.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
January 28	1.20	1,026	July 17	4.10	4,042
April 22	2.58	2,420	July 29	2.68	2,848
May 13	5.30	9,253	August 25	1.65	1,578
June 12	7.40	13,873	September 8	1.17	1,235
June 20	8.70	17,824	October 21	1.05	1,188

Daily gage height, in feet, of Blackfoot River at Bonner, Montana, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	0.75	.....	0.25	2.45	6.90	6.65	2.65	1.40	1.00	0.95	0.95
2	.....	.....	.....	.20	2.35	6.90	6.35	2.50	1.35	.95	1.00	1.45
3	.....	.....	1.65	.20	2.35	7.50	6.10	2.40	1.45	.95	.90	.80
4	.....	.....	1.40	.35	2.25	8.00	6.00	2.35	1.50	1.00	.90	.70
5	.....	.....	.85	.45	2.30	8.35	5.85	2.35	1.40	.75	1.15	.90
6	.....	.....	1.10	.60	2.55	8.00	5.60	2.30	1.40	.90	.95	.70
7	.....	.....	.85	.80	3.00	7.35	5.40	2.25	1.35	.85	.95	.85
8	.....	.....	.85	.80	3.45	6.75	5.35	2.20	1.35	.85	.95	.85
9	.....	.....	.60	1.10	4.10	6.30	5.35	2.20	1.35	.85	.90	.85
10	.....	.....	.50	2.30	5.00	6.15	5.35	2.15	1.30	.90	.90	.65
11	.....	.....	.55	3.35	5.30	6.55	5.25	2.15	1.25	1.00	.90	.70
12	.....	.....	.45	3.65	5.55	7.55	5.05	2.10	1.20	.85	.95	.75
13	.....	.....	.50	4.80	5.35	7.55	4.90	2.00	1.25	.90	.95	.70
14	.....	.....	.60	3.95	5.25	7.20	4.65	1.95	1.40	.80	.95	.75
15	.....	.....	.50	3.10	4.95	6.80	4.40	1.85	1.30	.90	.95	.60
16	.....	.....	.55	3.05	4.70	6.80	4.30	1.80	1.20	.90	.95	.55
17	.....	.....	.40	2.75	4.70	7.25	4.10	1.85	1.15	.95	.95	.50
18	.....	.....	.55	2.65	4.70	7.85	4.00	1.80	1.10	.95	.85	.75
19	.....	.....	.25	2.55	4.85	8.55	3.85	1.75	1.15	.90	1.25	.90
20	.....	.90	.35	2.25	4.80	8.70	3.90	1.75	1.30	.95	.90	1.00
21	.....	.65	.30	2.45	4.85	8.45	3.75	1.75	1.10	1.15	.90	.85
22	0.65	1.65	.25	2.67	4.85	7.75	3.55	1.75	1.05	1.00	.95	.95
23	.60	.....	.35	2.80	5.05	7.10	3.55	1.95	1.00	1.00	.90	.85
24	.85	.....	.35	2.45	5.25	6.80	3.25	1.80	.90	1.05	.80	1.15
25	.70	.....	.40	2.45	6.20	6.65	3.10	1.70	1.10	.95	.95	1.10
26	.75	.....	.20	3.05	7.10	6.95	3.05	1.65	1.00	1.00	1.05	1.15
27	1.00	.....	.30	3.25	7.65	7.10	2.80	1.65	1.05	.95	.95	.95
28	1.05	.....	.15	3.05	7.60	6.65	2.75	1.70	1.00	.95	.85	.75
29	.95	.....	.20	2.80	7.10	6.55	2.70	1.65	1.05	.95	.90	.50
30	.90	.....	.30	2.60	7.25	6.80	2.70	1.45	.90	.95	.80	.55
31	1.00	.....	.20	.....	7.00	.....	2.65	1.45	.....	1.00	.....	.70

RATTLESNAKE CREEK AT MISSOULA, MONTANA.

This is a stream having its source north of Missoula and draining a small extent of country. It enters Missoula River in the city of Missoula. The most important application of this stream is by the Missoula waterworks, for the water supply of the city of Missoula. About 15 second-feet are used for this purpose. Twelve ditches, with a capacity of from 1 to 10 second-feet each, divert water from the creek and irrigate lands in Rattlesnake Valley and in the vicinity of Missoula. Another ditch, with a capacity of 20 second-feet, diverts water from the mouth of the stream and is used for power purposes in a cabinet shop in the town of Missoula. At a medium stage of water in 1899 this stream was carrying 108 second-feet above the ditch diversions. At the same time it was discharging into Missoula River 45 second-feet, the difference, 63 second-feet, being used for power and irrigation purposes. The station was established May 27, 1899, and is located at the Ivy street bridge in the center of the city. The bench mark is the top of the capstone of the stone steps of the house owned by Thomas Greenough, 25 yards southeast from the gage and 1.983 feet above center of axle of the pulley of the gage. Between May 27 and September 7 a stretch of 0.15 foot was noticed, and the records, as published, have been correspondingly corrected.

The following discharge measurements were made during 1899 under the direction of Prof. F. D. Smith:

Discharge measurements of Rattlesnake Creek at Missoula, Montana.

1899.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
May 30	4.55	653	July 28	3.20	124
June 12	6.05	1,712	August 22	2.85	63
June 17	5.70	1,695	September 7	2.85	68
July 4	5.00	1,097	September 28	2.60	47
July 12	4.30	570			

Daily gage height, in feet, of Rattlesnake Creek at Missoula, Montana, for 1899.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	4.35	5.00	2.98	2.68	2.53	2.85	2.98
2	.....	4.65	5.13	2.98	2.68	2.50	2.85	2.98
3	.....	4.90	5.03	2.95	2.73	2.50	2.83	3.00
4	.....	5.03	4.95	2.90	2.90	2.50	2.80	3.00
5	.....	4.98	5.00	2.80	2.80	2.50	2.93	2.98
6	.....	4.60	4.78	2.73	2.83	2.60	2.75	2.95
7	.....	4.35	4.70	2.68	2.83	2.50	2.75	2.93
8	.....	4.20	4.70	2.78	2.78	2.50	2.73	2.93
9	.....	4.23	4.70	2.88	2.80	2.55	2.70	2.90
10	.....	4.70	4.58	2.88	2.73	2.58	2.75	2.88
11	.....	6.05	4.50	2.85	2.68	2.55	2.83	2.85
12	.....	5.95	4.38	2.80	2.70	2.58	2.88	2.80
13	.....	5.20	4.30	2.75	2.80	2.58	2.85	2.80
14	.....	4.85	4.18	2.78	2.80	2.50	2.80	2.73
15	.....	4.68	4.10	2.75	2.80	2.58	2.78	2.35
16	.....	5.18	3.98	2.75	2.80	2.58	2.75	2.30
17	.....	5.90	3.80	2.70	2.78	2.65	2.75	(a)
18	.....	6.25	3.83	2.68	2.75	2.63	2.75	(a)
19	.....	6.18	3.73	2.68	2.73	2.65	2.75	(a)
20	.....	6.05	3.63	2.65	2.68	2.90	2.75	(a)
21	.....	5.12	3.60	2.78	2.68	2.98	2.75	(a)
22	.....	4.88	3.60	2.80	2.65	2.90	2.70	(a)
23	.....	4.70	3.58	2.85	2.60	2.90	2.73	(a)
24	.....	5.00	3.43	2.88	2.60	2.88	2.68	2.90
25	.....	5.40	3.40	2.75	2.55	2.88	2.65	2.95
26	.....	5.73	3.35	2.78	2.55	2.85	2.70	3.05
27	5.15	5.35	3.33	2.88	2.55	2.85	2.73	3.00
28	4.78	5.05	3.23	2.73	2.55	2.88	2.98	2.90
29	4.45	5.35	3.13	2.68	2.55	2.90	3.05	3.00
30	4.65	5.33	3.03	3.65	2.58	2.85	3.03	2.85
31	4.40	.....	3.08	2.68	.....	2.85	.....	.....

a December 17 to 23 no readings.

MISSOULA RIVER AT MISSOULA, MONTANA.

This river has its source in Silverbow County and flows northerly until it receives the waters of Little Blackfoot River, when it takes a more northwesterly course. The name Missoula is usually applied to that section of the river between the junction of Blackfoot and Hellgate rivers and the mouth of Pend Oreille River. The name usually applied to it from this point down to its junction with Columbia River is Clark Fork of the Columbia. The station, established July 10, 1898, is located at Higgins avenue bridge in Missoula. The river at this point flows in two channels, and in order to study their fluctuations a second rod was placed on the south channel January 28, 1899.

This second rod is vertical and attached to the pier of the bridge. The readings of the two rods were made to correspond on the date of the establishment of the second rod, and they were 2.85 feet. The original rod is known as rod No. 1, and the gage in the south channel is known as rod No. 2. Discharge measurements are always made at the bridge of the Bitterroot Valley division of the Northern Pacific Railway some distance below the Higgins avenue bridge. The river at this point is practically in one channel, except in times of flood, when some water finds its way through a slough 600 feet south of the bridge. On account of the difficulty of accurately measuring the fluctuations of the river at rods Nos. 1 and 2 a third rod was placed May 27, 1899, below the junction of the two branches and 150 yards east of the railroad bridge. The rod at this point consists of a horizontal 20-foot timber bolted to a cottonwood tree immediately below the buildings of the Garden City Bottling Works. The rod is securely braced with timbers both above and below and guyed by wires on both sides. To the horizontal timber is attached a wire gage, the length of which is 22 feet. The bench mark consists of a United States Geological Survey iron post, at the junction of McCormick and West Cedar streets, 100 yards west of the gage, on the north side of the highway. Its elevation above sea is 3,194.642 feet. The top of the horizontal bar of the gage at a point exactly over the iron bolt which holds the rod to the cottonwood tree is 3,178.338 feet. The height of the river was read at the three rods during 1899, but observations during 1900 will only be taken at rod No. 3, the other two being discontinued. The results of measurements for 1898 may be found in the Twentieth Annual Report, Part IV, page 491. Measurements for 1898 and 1899 were made under the direction of F. D. Smith and are as follows:

Discharge measurements of Missoula River at Missoula, Montana.

1899.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
April 22	a 4.75	6,876	August 1	5.35	4,822
May 30	9.50	23,295	August 24	4.75	3,127
June 19	10.55	34,634	September 8	4.15	2,492
July 6	8.30	17,872	October 21	4.10	2,273.
July 14	7.30	9,235			

a Gage height at rod No. 1. The other gage heights were taken on rod No. 3.

Daily gage height, in feet, of Missoula River at Missoula, Montana, for 1899.

[Rod No. 1.]

Day.	Jan.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	.....	.....	2.33	4.15	9.10	8.90	4.35	3.33	2.95
2	.....	.....	2.35	4.15	8.95	8.50	4.30	3.30	2.95
3	.....	.....	2.40	3.95	9.60	8.30	4.28	3.33	2.95
4	.....	.....	2.50	3.80	10.10	8.15	4.20	3.38	2.95
5	.....	.....	2.70	3.80	10.50	8.00	4.20	3.38	2.95
6	.....	.....	3.00	4.15	10.30	7.75	4.08	3.33	2.95
7	.....	2.30	3.33	4.50	9.60	7.38	4.00	3.20	2.95
8	.....	2.35	3.63	5.10	8.80	7.35	4.00	3.20	2.95
9	.....	2.48	3.73	5.75	8.35	7.40	4.03	3.15	2.95
10	.....	2.50	4.87	6.70	8.40	7.33	4.05	3.15	2.95
11	.....	2.55	5.85	7.05	9.15	7.25	4.00	3.13	2.95
12	.....	2.58	6.20	7.30	10.08	6.98	3.95	3.10	2.95
13	.....	2.60	7.60	7.15	9.90	6.75	3.93	3.10	3.00
14	.....	2.38	6.40	6.95	9.65	6.50	3.95	3.10	2.98
15	.....	.....	4.95	6.65	9.43	6.38	3.90	3.10	2.93
16	.....	2.15	4.95	6.45	9.45	6.23	3.80	3.10	2.98
17	.....	2.15	4.78	6.40	9.85	5.90	3.75	3.03	3.00
18	.....	2.20	4.55	6.40	10.60	5.65	3.70	3.00	3.00
19	.....	2.18	4.40	6.35	10.90	5.48	3.68	3.00	2.98
20	.....	2.28	4.05	6.45	11.30	5.43	3.63	2.95	3.00
21	.....	2.25	3.98	6.50	10.73	5.38	3.63	2.95	3.03
22	.....	2.20	4.53	6.55	10.10	5.30	3.70	2.95	3.03
23	.....	2.15	4.70	6.75	9.35	5.15	3.75	2.95	3.00
24	.....	2.28	4.35	7.05	8.95	4.90	3.73	2.95	3.00
25	.....	2.35	4.28	8.00	9.05	4.73	3.70	2.95	3.05
26	.....	2.35	4.83	9.10	9.50	4.68	3.63	2.95	3.00
27	.....	2.48	4.95	9.80	9.70	4.60	3.55	2.95	3.05
28	.....	2.58	4.70	9.75	9.15	4.53	3.50	2.90	3.00
29	2.80	2.58	4.45	9.35	9.00	4.50	3.50	2.90	2.95
30	2.75	2.40	4.25	9.30	9.10	4.40	3.45	2.90	2.93
31	2.75	2.30	.....	9.15	.....	4.30	3.43	.....	2.90

No record for February; ice.

Station discontinued October 31.

Daily gage height, in feet, of Missoula River at Missoula, Montana, for 1899.

[Rod No. 2.]

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	.....	2.50	3.80	7.60	7.25	3.83	3.20	2.95
2	.....	2.50	3.70	7.28	6.98	3.88	3.20	2.95
3	.....	2.55	3.60	7.80	6.78	3.83	3.23	2.95
4	.....	2.60	3.50	8.20	6.65	3.75	3.20	2.95
5	.....	2.75	3.60	8.60	6.55	3.78	3.20	2.95
6	.....	2.90	4.00	8.45	6.35	3.73	3.15	2.95
7	.....	3.10	4.20	7.65	7.13	3.63	3.15	2.95
8	.....	3.30	4.60	7.15	6.00	3.65	3.15	2.95
9	.....	3.50	5.30	6.85	6.00	3.65	3.13	2.95
10	.....	4.70	5.60	6.75	6.00	3.70	3.05	3.00
11	2.50	5.30	6.00	7.40	5.98	3.68	3.03	3.05
12	2.58	5.30	6.20	8.35	5.88	3.60	3.00	3.05
13	2.60	6.20	5.90	8.35	5.55	3.60	3.00	3.08
14	(a)	4.80	5.75	7.90	5.48	3.65	3.00	3.05
15	(a)	4.30	5.60	7.43	5.40	3.53	3.05	2.93
16	(a)	4.50	5.50	7.45	5.20	3.45	3.03	3.08
17	2.40	4.20	5.40	7.80	5.00	3.45	3.05	3.05
18	2.28	4.20	5.30	8.65	4.80	3.40	3.00	3.05
19	2.28	3.90	5.80	8.80	4.73	3.35	3.00	3.03
20	2.40	3.70	5.40	8.90	4.54	3.40	2.98	3.15
21	(a)	3.70	5.40	8.85	4.50	3.40	2.95	3.08
22	(a)	4.20	5.50	8.40	4.48	3.48	2.95	3.10
23	(a)	4.10	5.70	7.90	4.43	3.50	2.95	3.05
24	2.40	3.90	5.80	7.45	4.28	3.45	5.95	3.10
25	2.45	4.00	6.80	7.50	4.20	3.43	2.95	3.05
26	2.55	4.30	7.60	8.05	4.00	3.38	2.98	3.05
27	2.60	4.40	8.00	7.80	4.00	3.33	2.95	3.10
28	2.55	4.10	7.80	7.48	3.90	3.30	2.90	3.05
29	2.61	3.90	7.40	7.40	3.90	3.30	2.90	3.00
30	2.50	3.80	7.50	7.48	3.85	3.25	2.90	2.98
31	2.45	.....	7.50	.....	3.85	3.23	.....	2.95

a Ice.

Station discontinued October 31.

Daily gage height, in feet, of Missoula River at Missoula, Montana, for 1899.

[Rod No. 3.]

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	9.30	9.30	5.40	4.25	3.78	3.98	3.95
2	.....	9.22	8.95	5.35	4.28	3.75	3.95	3.93
3	.....	9.60	8.75	5.25	4.28	3.75	3.90	3.88
4	.....	10.00	8.60	5.10	4.33	3.75	3.95	3.60
5	.....	10.23	8.55	5.08	4.33	3.75	3.95	3.58
6	.....	10.05	8.33	4.98	4.25	3.75	3.98	3.60
7	.....	10.38	8.13	4.83	4.18	3.75	3.93	3.60
8	.....	9.10	8.05	4.95	4.15	3.75	3.90	3.65
9	.....	8.78	8.03	5.08	4.13	3.75	3.95	3.75
10	.....	8.78	8.00	5.15	4.10	3.75	3.93	3.70
11	.....	9.38	7.98	5.12	4.08	3.80	3.90	3.70
12	.....	10.05	7.73	5.00	4.05	3.80	3.93	3.75
13	.....	10.05	7.58	4.90	4.05	3.88	3.98	3.80
14	.....	9.73	7.38	4.93	4.05	3.80	3.95	3.80
15	.....	9.43	7.20	4.78	4.08	3.68	3.98	3.80
16	.....	9.28	6.95	4.73	4.08	3.88	3.88	.....
17	.....	9.80	6.88	4.65	4.05	3.95	3.88	.....
18	.....	10.38	6.70	4.56	4.00	3.98	3.90	.....
19	.....	10.55	6.48	4.58	4.00	4.08	3.90	.....
20	.....	10.65	6.43	4.70	3.98	4.10	3.90	.....
21	.....	10.45	6.33	4.65	3.90	4.10	3.95	.....
22	.....	10.08	6.23	4.73	3.90	4.20	3.90	.....
23	.....	8.95	6.13	4.85	3.85	4.15	3.88	.....
24	.....	9.30	5.98	4.75	3.75	4.18	3.83	.....
25	.....	9.30	5.83	4.65	3.80	4.10	3.75	.....
26	.....	9.58	5.68	4.52	3.78	4.08	3.65	.....
27	9.85	9.65	5.50	4.50	3.78	4.15	3.75	.....
28	9.80	9.38	5.45	4.50	3.75	4.05	3.88	.....
29	9.55	9.25	5.45	4.48	3.75	4.00	3.98	.....
30	9.55	9.33	5.40	4.38	3.75	3.98	3.95	.....
31	9.45	.....	5.40	4.28	.....	3.95	.....	.....

BITTERROOT RIVER AT COMO, MONTANA.

The main source of supply of this river is in the high mountains forming the boundary line between Montana and Idaho. The general direction of the stream is northerly, entering Missoula River a short distance below the city of Missoula. The tributaries on the east side drain comparatively low hills and contribute little to the supply of the river. The west-side branches, on the contrary, are numerous, draining a precipitous and heavily wooded area. Their discharges are regulated by many small lakes fed by banks of snow which continue far into the summer season before disappearing altogether. In the vicinity of Hamilton are a number of large canals, the principal ones diverting water on the east side of the river for use by the Bitterroot Stock Farm. The higher bench lands west of the river are served by small ditches taken directly from the smaller tributaries. The ranchers on these bench lands have within the last few years increased the summer flow of their ditches by the construction of rude gates at the outlets of a number of the lakes on the headwaters of the side streams. This is done at the heads of Canyon, Bear, and Big creeks. An additional supply can be had by utilizing Lake Como. This lake is about 1 mile long and one-half mile wide and is near the mouth of Rock Creek. The gaging station, established by Cyrus C.

Babb in October, 1898, is located at the Harlan bridge near Como, and is 9 miles south of Grantsdale, Montana. A wire gage was placed on the downstream hand-rail of the bridge, and later a vertical rod was fastened to the upstream side of the south pier. The bench mark is on a cottonwood tree 10 feet west of the south end of the bridge, and is at an elevation of 6.10 feet above gage datum. The right bank of the river is high, while the left bank is low and liable to overflow. Gage readings have not yet been maintained at this point, and but one discharge measurement was made during 1899. H. S. Lord, on January 21, 1899, at a gage height of 1 foot, found a discharge of 384 second-feet.

BITTERROOT RIVER AT MISSOULA, MONTANA.

The fall of this river from Hamilton to Missoula, a distance of 48 miles, is 350 feet, or 7.3 feet to the mile. The lower portion of Bitterroot Valley has not been as extensively cultivated as the section in the vicinity of Hamilton. There is a good flow of water in the river, but owing to the lighter grade of the lower country a greater length of canal is necessary than in the upper section, and therefore this latter district has been first developed. The gaging station is located at the Buckhouse wagon bridge, on the main road southwest of Missoula, and was established July 6, 1898. The bench mark is the regulation iron post of the United States Geological Survey, set 25 yards northwest of the bridge, near a fence at the side of the highway, and is 3.801 feet above the center of the axle of the gage pulley. The length of the gage wire is 22.83 feet. The channel of the river is nearly straight. The right bank is low and liable to overflow, but the left bank is high and rocky. The results obtained at the Buckhouse bridge, which is near the mouth of the river, are of value mainly in giving the total discharge of the stream. The results of measurements for 1898 may be found in the Twentieth Annual Report, Part IV, page 495. The following measurements of discharge were made under the direction of F. D. Smith in 1899:

Discharge measurements of Bitterroot River at Missoula, Montana.

1899.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
April 29	3.75	3,794	July 17	7.21	11,569
May 16	5.18	7,405	August 1	4.55	5,410
June 10	6.70	11,732	August 25	2.78	2,595
June 17	9.00	20,355	October 21	2.18	1,810
June 20	11.40	37,012			

Daily gage height, in feet, of Bitterroot River at Missoula, Montana, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	(a)	(a)	1.25	1.55	3.50	6.80	9.60	4.55	2.40	1.55	2.30	1.90
2	(a)	(a)	1.25	1.70	3.40	6.70	9.55	4.50	2.35	1.60	2.15	2.00
3	(a)	(a)	1.30	1.75	3.20	7.15	9.40	4.30	2.40	1.70	2.05	2.00
4	(a)	(a)	1.35	1.80	3.10	8.30	9.20	4.10	2.50	1.70	2.00	1.80
5	(a)	(a)	1.40	1.80	3.00	8.90	9.10	4.00	2.60	1.65	2.00	1.80
6	(a)	(a)	1.45	1.95	3.30	8.00	9.05	4.05	2.50	1.60	2.00	1.90
7	(a)	(a)	1.50	1.95	3.45	7.20	8.75	4.00	2.45	1.60	2.00	1.94
8	(a)	(a)	1.70	2.05	3.90	6.80	8.70	4.05	2.30	1.55	1.95	1.95
9	(a)	(a)	1.65	2.15	4.90	6.70	8.85	4.10	2.25	1.55	1.95	1.96
10	(a)	(a)	1.60	2.50	5.98	6.75	8.95	4.15	2.20	1.60	2.00	1.80
11	(a)	(a)	1.55	2.80	6.30	7.95	8.90	4.10	2.10	1.60	2.00	1.80
12	(a)	(a)	1.45	3.20	6.45	9.40	8.85	4.00	2.05	1.60	2.05	1.85
13	(a)	(a)	1.40	3.80	6.40	10.80	8.60	3.70	2.10	1.65	2.00	1.75
14	(a)	(a)	1.35	3.65	6.25	10.50	8.10	3.50	2.30	1.65	1.95	1.75
15	(a)	(a)	1.40	3.45	6.00	9.20	7.75	3.40	2.25	1.70	1.90	1.80
16	(a)	(a)	1.40	3.50	5.20	8.50	7.50	3.25	2.25	1.70	1.95	(a)
17	1.50	(a)	1.35	3.50	5.00	8.98	7.50	3.05	2.15	1.75	2.00	(a)
18	1.55	(a)	1.40	3.60	4.70	9.90	7.20	3.00	2.10	1.80	2.00	(a)
19	1.55	(a)	1.40	3.65	4.65	10.95	7.15	2.85	2.10	1.80	2.00	(a)
20	1.60	(a)	1.40	3.45	4.60	11.45	7.00	3.50	2.00	1.90	1.90	(a)
21	1.65	(a)	1.40	3.40	4.60	11.28	6.95	2.95	1.90	2.10	1.85	(a)
22	1.65	(a)	1.40	3.30	4.60	11.13	6.60	3.10	1.80	2.25	1.85	(a)
23	1.70	(a)	1.35	3.50	5.00	9.65	5.95	3.20	1.80	2.40	1.80	(a)
24	1.70	(a)	1.55	3.70	5.48	9.40	5.50	3.00	1.75	2.30	1.75	(a)
25	1.65	(a)	1.55	3.75	5.90	9.10	5.15	2.85	1.75	2.25	1.70	1.65
26	1.70	(a)	1.60	3.80	7.40	9.80	5.00	2.75	1.65	2.30	1.60	1.65
27	1.80	(a)	1.65	3.95	7.95	10.20	4.85	2.70	1.60	2.50	1.70	1.60
28	1.80	(a)	1.65	4.00	7.70	9.90	4.80	2.65	1.60	2.55	1.80	1.60
29	(a)	.....	1.66	3.75	7.30	9.60	4.75	2.60	1.65	2.60	1.90	1.68
30	(a)	.....	1.65	3.60	7.50	9.85	4.75	2.50	1.55	2.55	1.90	1.70
31	(a)	.....	1.60	.....	6.95	.....	4.60	2.45	.....	2.40	.....	1.70

a Frozen.

SPOKANE RIVER AND LAKE CŒUR D'ALENE.

This river receives the outflow of Lake Cœur d'Alene, the outlet being at the northern end of the lake near the town of Cœur d'Alene. The greater part of the lake is shown on the topographic atlas sheet of the same name. The bench mark near the lake was established by Mr. Van H. Manning in 1899. From his notes it appears that this bench mark, consisting of an aluminum tablet in the southeast corner of the Merriam Building, corner of Sherman and Fourth streets, Cœur d'Alene, Idaho, is 2 feet above the sidewalk and 1 foot from the door, at an elevation of 2,157.404 feet. The bench mark at the lake consists of a spike in a cottonwood tree at Johnson's boat landing. This is at an elevation of 2,130.645 feet. When placed, May 20, 1899, it was at the exact surface of the water of the lake. The fluctuations of lake level during 1899 are shown by the following readings by Mr. Manning:

Elevation of water surface of Lake Cœur d'Alene.

1899.

Date.	Elevation.
	Feet.
May 20	2,130.645
May 23	2,130.000
July 3	2,128.242
July 24	2,123.643
August 5 (5 p. m.)	2,122.551
August 28	2,121.469

The level of the water in the lake is influenced by a dam at Post Falls, 8¾ miles below the outlet of the lake. On August 5, at 3.30 p. m., the elevation of the surface of the water at the dam at Post Falls was 2,119.580 feet. Observations were made on the same day, at 5 p. m., at Cœur d'Alene, giving the elevation of water surface above noted—2,122.551 feet—and showing a difference of 2.971 feet between the lake surface and the water in the river at the dam. It is proposed to maintain occasional observations of the height of water at Cœur d'Alene.

Fernan Lake is a small body of water 2 miles east of the town of Cœur d'Alene. A bench mark has been established at the west end of the lake on a stone about 20 inches by 30 inches, 20 inches in diameter, 15 feet north of and 200 feet east of Fernan's house. The cross on this stone is at an elevation of 2,133.16 feet. The surface of the lake on August 18, 1899, was at a height of 2,129.028 feet.

Hayden Lake is east of Rathdrum Prairie and about 6 miles north of Cœur d'Alene. Although a body of water of considerable size and receiving drainage from a mountain area it has no visible outlet. A bench mark has been placed at the west end of the lake and consists of a nail in a pine tree 40 feet north of and 200 feet east of gate to King's ranch. Its elevation is 2,261.495 feet. The surface of the lake on August 10, 1899, was 2,242.764 feet; on August 29, 2,242.666 feet: on October 10, 2,241.369 feet.

Spirit Lake is a small body of water 12 miles north of Rathdrum Prairie. An iron post marked "2,490 S" has been placed at the east end of the lake, 200 feet east of the landing and 15 feet south of the road. The correct elevation is 2,489.993 feet. The elevation of the lake surface on September 14, 1899, was 2,444.037 feet.

Fish Lake is 3 miles north of Rathdrum. An iron post marked "2,366 S" has been placed one-fourth of a mile east of the south end of the lake and 8 feet east of the fork of the roads. The elevation is 2,365.706 feet. The elevation of lake surface on September 4, 1899, was 2,314.016 feet. Irrigation of Rathdrum Prairie has been begun by the Spokane Valley Irrigation Company.

Pend Oreille Lake is the source of Clark Fork of the Columbia. The elevation of its surface on September 22, 1899, as determined by Mr. Van H. Manning, was 2,055 feet.

SPOKANE RIVER AT SPOKANE, WASHINGTON.

The falls at Spokane, aggregating 142 feet in height, have been utilized to a considerable extent by a number of flour mills, as well as by the power plant of the Washington Water Power Company, which furnishes electric power for the street-car service and for the lighting of the city. The river station established October 17, 1896, is located a short distance above the falls, at the bridge of the Oregon Railroad and Navigation Company. The length of the wire gage is 22 feet. The gage was connected with the bench mark of the city engineering

department and referred to sea level, the zero being 1,880 feet above sea level. The banks are high and do not overflow except in unusual floods. The velocity is quite swift, even at low stages. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 359; 1897, Nineteenth Annual Report, Part IV, page 488; 1898, Twentieth Annual Report, Part IV, page 511. One measurement of discharge was made here during 1899 by Sydney Arnold, on June 23, when at a gage height of 9.30 feet a discharge of 23,258 second-feet was found.

Daily gage height, in feet, of Spokane River at Spokane, Washington, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.40	5.50	3.75	3.65	8.65	10.60	8.30	3.75	2.40	2.00	2.40	3.95
2	2.50	5.40	3.75	3.70	8.50	10.55	8.20	3.75	2.40	2.00	2.40	4.50
3	2.60	5.25	3.75	3.75	8.40	10.40	8.00	3.75	2.40	2.00	2.40	5.00
4	2.60	5.10	3.70	3.80	8.20	10.45	7.80	3.70	2.40	2.00	2.40	5.30
5	2.60	5.00	3.65	3.90	8.00	10.60	7.60	3.70	2.40	2.00	2.35	5.35
6	2.55	4.85	3.65	4.00	7.90	10.70	7.40	3.60	2.40	1.90	2.35	5.40
7	2.55	4.70	3.60	4.10	7.70	10.65	7.15	3.50	2.40	1.90	2.35	5.35
8	2.50	4.60	3.60	4.35	7.80	10.50	7.05	3.40	2.40	1.95	2.35	5.25
9	2.50	4.50	3.65	4.45	8.05	10.35	6.85	3.30	2.40	1.95	2.35	5.20
10	2.50	4.40	3.70	4.85	8.55	10.10	6.70	3.30	2.40	1.90	2.35	5.10
11	2.50	4.30	3.80	5.05	9.00	10.00	6.50	3.25	2.40	1.90	2.35	4.90
12	2.50	4.20	3.85	5.45	9.45	9.85	6.40	3.10	2.30	1.90	2.30	4.85
13	2.50	4.10	3.85	6.20	9.90	9.89	6.30	3.00	2.30	1.90	2.30	4.75
14	2.50	4.05	3.85	6.90	10.20	9.85	6.20	2.95	2.30	1.90	2.30	4.70
15	2.60	4.00	3.85	7.40	10.35	9.85	6.10	2.90	2.30	1.90	2.30	4.65
16	2.60	3.90	3.85	7.50	10.35	9.75	5.85	2.85	2.30	1.90	2.30	4.55
17	2.60	3.90	3.85	7.85	10.20	9.60	5.70	2.85	2.30	1.90	2.30	4.40
18	2.60	3.85	3.80	8.00	10.10	9.60	5.60	2.80	2.30	1.90	2.30	4.25
19	2.60	3.85	3.70	8.20	10.00	9.70	5.25	2.75	2.25	1.90	2.50	4.10
20	2.85	3.90	3.65	8.30	9.85	9.74	5.05	2.75	2.20	1.95	2.50	4.00
21	2.95	3.95	3.65	8.30	9.70	9.70	4.90	2.75	2.20	2.00	2.65	3.90
22	3.65	3.95	3.70	8.25	9.50	9.60	4.75	2.75	2.15	2.10	2.80	3.85
23	4.55	3.90	3.70	8.20	9.50	9.50	4.65	2.75	2.15	2.20	2.85	3.80
24	5.20	3.90	3.70	8.20	9.50	9.40	4.50	2.65	2.15	2.25	2.90	3.90
25	5.60	3.90	3.70	8.15	9.70	9.30	4.45	2.60	2.10	2.30	2.90	4.15
26	5.55	3.90	3.70	8.15	9.95	9.15	4.30	2.60	2.10	2.35	2.90	4.50
27	5.55	3.80	3.65	8.35	10.25	8.85	4.20	2.55	2.10	2.35	3.00	4.75
28	5.55	3.80	3.60	8.60	10.55	8.55	4.00	2.55	2.10	2.35	3.00	4.90
29	5.55	.....	3.60	8.70	10.80	8.50	3.90	2.55	2.05	2.35	3.20	4.90
30	5.55	.....	3.60	8.70	10.80	8.40	3.80	2.50	2.05	2.35	3.50	4.80
31	5.60	.....	3.65	.....	10.80	.....	3.75	2.45	.....	2.40	.....	4.70

LAKE CHELAN AT LAKESIDE, WASHINGTON.

This lake is situated in the north-central part of Washington, on the eastern slope of the Cascade Mountains. The streams which contribute to it have their sources in the glaciers, and thus there is a constant supply. The outlet of the lake is at the southern extremity, through Chelan River, which empties into Columbia River 4 miles below. The lake itself is very deep, a depth of 1,400 feet having been found by soundings made by the topographers of the United States Geological Survey. As the surface of the lake is at an elevation of about 1,100 feet, this would show that the bottom was about 300 feet below sea level. The country surrounding the lower extremity of this body of water is of a rolling character and is largely used for grazing purposes. The gage on the lake was established by Capt. Charles Johnson September 1, 1897, at the base of the rock pier on the lake shore north of his house, about one-half mile from the steamboat landing.

The bench mark is a United States Geological Survey iron post, with the elevation—1,121 feet above sea level—stamped on the top. This bench mark is just 21 feet above datum of the gage, so that to obtain the elevation of the surface of the lake above sea level 1,100 feet should be added to the rod readings.

Daily gage height, in feet, of Lake Chelan at Lakeside, Washington, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	7.10	7.85	7.35	6.85	7.40	10.10	11.60	10.90	8.45	7.70	7.05	7.90
2	7.20	7.85	7.35	6.90	7.45	10.10	11.55	10.85	8.40	7.70	7.10	7.95
3	7.30	7.80	7.30	6.90	7.45	10.20	11.55	10.80	8.40	7.70	7.20	7.95
4	7.35	7.75	7.30	6.90	7.45	10.40	11.60	10.65	8.35	7.65	7.25	7.95
5	7.35	7.70	7.30	6.95	7.50	10.60	11.65	10.60	8.35	7.65	7.30	8.00
6	7.40	7.65	7.25	6.95	7.50	10.65	11.70	10.60	8.30	7.60	7.35	8.00
7	7.45	7.60	7.25	7.00	7.55	10.65	11.70	10.55	8.25	7.55	7.40	8.05
8	7.45	7.60	7.25	7.00	7.65	10.70	11.60	10.50	8.25	7.50	7.45	8.05
9	7.50	7.55	7.20	7.05	7.85	10.70	11.55	10.40	8.20	7.50	7.50	8.10
10	7.50	7.50	7.20	7.10	8.00	10.75	11.55	10.30	8.15	7.45	7.55	8.10
11	7.45	7.50	7.15	7.10	8.20	10.85	11.60	10.20	8.10	7.40	7.55	8.15
12	7.45	7.45	7.15	7.15	8.30	11.00	11.60	10.10	8.10	7.35	7.60	8.15
13	7.40	7.45	7.15	7.15	8.40	11.10	11.65	10.05	8.05	7.30	7.65	8.20
14	7.45	7.40	7.10	7.15	8.45	11.15	11.70	10.00	8.05	7.25	7.65	8.20
15	7.45	7.85	7.10	7.20	8.50	11.20	11.75	*9.85	8.00	7.25	7.70	8.20
16	7.45	7.35	7.05	7.20	8.50	11.35	11.75	9.75	8.00	7.20	7.75	8.25
17	7.50	7.30	7.05	7.25	8.55	11.60	11.80	9.65	7.95	7.15	7.80	8.25
18	7.50	7.30	7.00	7.25	8.55	11.65	11.80	9.60	7.95	7.15	7.85	8.20
19	7.55	7.30	7.00	7.25	8.60	11.65	11.75	9.50	7.90	7.10	7.90	8.20
20	7.60	7.35	7.00	7.25	8.65	11.70	11.70	9.40	7.90	7.10	7.90	8.25
21	7.60	7.35	6.95	7.30	8.70	11.65	11.65	9.35	7.90	7.05	7.95	8.25
22	7.60	7.35	6.95	7.30	8.80	11.60	11.60	9.30	7.90	7.05	8.00	8.30
23	7.65	7.30	6.90	7.35	8.90	11.60	11.40	9.25	7 85	7 00	8.00	8.30
24	7.65	7.30	6.90	7.35	9.05	11.65	11.30	9.10	7.85	7.00	8.00	8.35
25	7.60	7.25	6.90	7.35	9.30	11.85	11.20	9.00	7.80	7.05	7.95	8.35
26	7.60	7.25	6.85	7.40	9.70	11.75	11.05	8.90	7.80	7.10	7.95	8.40
27	7.65	7.30	6.85	7.40	9.90	11.70	11.00	8.80	7.80	7.10	7.90	8.40
28	7.70	7.30	6.80	7.45	10.00	11.60	10.95	8.75	7.75	7.05	7.85	8.40
29	7.75	.....	6.80	7.40	10.00	11.55	11.00	8.70	7.75	7.05	7.85	8.45
30	7.75	.....	6.80	7.40	10.00	11.60	11.00	8.60	7.75	7.00	7.90	8.45
31	7.80	.....	6.85	.....	10.05	.....	11.00	8.50	.....	7.00	.....	8.50

NACHES RIVER AT NORTH YAKIMA, WASHINGTON.

This river has its source on the eastern slope of the Cascade Mountains in Yakima County, Washington. It flows in a general southeasterly direction, entering Yakima River a short distance above the town of North Yakima. Irrigation is practiced in the narrow valley along the lower course of the river, but its waters are of greater value for the irrigation of lands west of North Yakima. The river has considerable fall, and the water can be easily diverted by means of comparatively short canals. On this account it is of more value for irrigation purposes than Yakima River, which has less fall. The original station was established August 14, 1893, but was abandoned in 1897. It was reestablished February 1, 1898, and is now located near the Northern Pacific railway bridge at the mouth of the river. Owing to the fact that the wire gage was removed a number of times, an inclined rod was established June 20, 1899, with its zero 1.64 feet below the datum of the old gage; consequently, all heights recorded previous to June 20 should be increased by this amount to make them agree with those recorded since that date. The bench mark is the top

of the north end of the east sill of clearance post, about 150 feet north of the railroad bridge, and is at an elevation of 25.406 feet above datum of new gage. The bed of the river is rocky and is not liable to change at ordinary stages, but during the excessive floods to which this stream is subject the section is liable to great change. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 355; 1898, Twentieth Annual Report, Part IV, page 503. The following discharge measurements were made by Sydney Arnold in 1899:

May 4, gage height, 5.35 feet; discharge, 1,847 second-feet.
May 12, gage height, 6.85 feet; discharge, 5,434 second-feet.
May 26, gage height, 7.10 feet; discharge, 6,753 second-feet.
July 27, gage height, 7.25 feet; discharge, 2,856 second-feet.
August 16, gage height, 6.35 feet; discharge, 1,357 second-feet.
September 20, gage height, 5.70 feet; discharge, 588 second-feet.

Daily gage height, in feet, of Naches River at North Yakima, Washington, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	5.50	4.80	4.60	5.40	6.80	8.50	7.10	6.00	.....	5.90	8.40
2	4.70	5.30	4.80	.....	5.40	6.90	.....	7.00	6.00	5.80	5.90	8.20
3	4.70	4.90	4.70	4.60	5.40	6.90	8.50	6.90	.....	5.70	5.80	.....
4	4.50	4.80	4.70	4.80	5.40	.....	8.50	6.80	6.00	5.70	5.80	7.70
5	4.40	.....	.....	4.90	5.50	6.90	8.40	6.80	6.00	5.60	.....	7.50
6	4.40	4.70	4.70	4.90	5.80	7.00	8.40	.....	5.90	5.60	5.80	7.30
7	4.30	4.70	4.70	5.00	.....	7.00	8.30	6.80	5.90	5.60	5.90	7.20
8	.....	4.80	4.70	5.10	6.40	7.10	8.30	6.70	5.80	.....	6.10	7.10
9	4.30	5.10	4.60	.....	6.80	7.10	.....	6.60	5.80	5.60	6.20	6.90
10	4.30	5.20	4.60	5.50	7.20	7.00	8.30	6.60	.....	5.60	6.40	.....
11	4.20	5.20	4.60	5.50	7.20	.....	8.30	6.60	5.80	5.60	6.50	6.70
12	4.20	.....	.....	5.70	7.20	.....	8.30	6.60	5.80	5.60	.....	6.60
13	4.10	5.10	4.50	5.70	6.80	.....	8.40	.....	5.80	5.50	6.50	6.60
14	4.10	5.00	4.50	5.50	.....	7.86	8.40	6.50	5.70	5.50	6.50	6.60
15	.....	5.00	4.40	5.50	6.50	.....	8.40	6.50	5.70	.....	7.20	6.50
16	4.30	5.00	4.40	.....	6.40	.....	.....	6.40	5.70	5.50	7.20	6.50
17	4.30	5.00	4.40	5.50	6.40	.....	8.40	6.40	.....	5.50	7.10	.....
18	4.40	5.10	4.40	5.40	6.30	.....	8.30	6.40	5.70	5.60	6.90	6.30
19	4.40	.....	.....	5.30	6.20	.....	8.20	6.30	5.70	5.80	.....	6.30
20	4.50	5.00	4.40	5.30	6.20	a8.85	8.00	.....	5.60	6.40	8.10	6.20
21	5.80	5.00	4.40	5.20	.....	8.80	7.80	6.30	5.60	6.30	8.00	6.20
22	.....	5.10	4.40	5.20	6.40	8.70	7.50	6.20	5.60	.....	7.60	7.00
23	6.30	5.10	4.40	.....	6.40	8.70	.....	6.20	5.60	6.00	7.20	7.40
24	6.10	5.00	4.40	5.20	6.50	8.70	7.30	6.20	.....	6.00	7.00	.....
25	5.80	5.00	4.40	5.30	6.50	.....	7.30	6.10	5.60	5.90	7.00	8.30
26	5.80	.....	.....	5.30	6.60	8.70	7.20	6.10	5.60	5.90	.....	8.20
27	5.70	4.90	4.40	5.40	6.60	8.60	7.20	.....	5.60	6.00	7.80	8.00
28	5.70	4.80	4.40	5.40	.....	8.60	7.30	6.10	5.60	6.20	9.00	7.80
29	.....	.....	4.50	5.50	6.60	8.50	7.40	6.10	5.70	.....	8.90	7.60
30	5.70	.....	4.50	.....	6.70	8.50	7.20	6.10	5.80	6.00	8.60	7.40
31	5.60	.....	4.60	.....	6.80	.....	.....	6.00	.....	6.00	.....	.....

a New gage, datum 1.64 lower than old gage.

YAKIMA RIVER AT UNION GAP, WASHINGTON.

This river has its source in Keechelus Lake, on the eastern slope of the Cascade Mountains, in Kittitas County, Washington. In a short distance it receives the waters of Kachess Lake, and 2½ miles above Cle Elum it receives the outlet of the last of the three large headwater lakes. The valley of Yakima River is comparatively narrow until it widens out in the vicinity of Ellensburg, where considerable irrigation is practiced. At the lower end of this valley it enters a canyon 20

miles long, and then flows into Selah Valley, which is only 4 miles in length. At the lower end of this opening the river passes through a narrow gap to enter Yakima Valley. This section is the most extensively irrigated area in Washington, and is served principally by canals from Naches River. Seven miles below North Yakima the river passes through what is known as Union Gap, and thence enters its lower valley, which extends to Kiona. Yakima River enters Columbia River 23 miles below this point and just above the town of Pasco. The gaging station, established August 14, 1893, is located at Union Gap, 6 miles below North Yakima, Washington, and 1,000 feet below the highway bridge. It is about 3 miles above the head gate of the Sunnyside canal. The gage rod is inclined and is attached to a willow stump and posts set in the ground. The bench mark is the highest point of a large rock mound 25 feet north of the gage and 10 feet east of the fence, and is at an elevation of 17.52 feet above gage datum. The equipment consists of cable, car, and tagged wire. The station is of value in showing the amount of water available for the extensive irrigable lands below. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 358; 1897, Nineteenth Annual Report, Part IV, page 479; 1898, Twentieth Annual Report, Part IV, page 500. The following measurements of discharge were made by Sydney Arnold in 1899:

May 8, gage height, 8.03 feet; discharge, 8,500 second-feet.
August 18, gage height, 6 feet; discharge, 3,777 second-feet.
September 16, gage height, 5 feet; discharge, 1,730 second-feet.
October 6, gage height, 4.77 feet; discharge, 1,479 second-feet.

Daily gage height, in feet, of Yakima River at Union Gap, Washington, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	7.00	7.20	6.40	5.80	7.00	8.80	8.40	6.70	5.50	4.90	5.50	8.50
2	6.70	6.90	6.40	5.90	7.10	8.90	8.30	6.60	5.50	4.90	5.40	8.20
3	6.40	6.60	6.30	5.60	7.10	8.90	8.30	6.60	5.50	4.90	5.40	8.00
4	6.00	6.30	6.30	5.60	6.70	9.50	8.20	6.50	5.40	4.80	5.50	7.80
5	5.90	6.30	6.20	6.10	7.00	9.80	8.20	6.50	5.40	4.80	5.40	7.40
6	5.60	6.30	6.20	6.10	7.20	9.50	8.10	6.50	5.40	4.80	5.40	7.00
7	5.30	6.30	6.10	6.20	7.50	9.00	8.10	6.40	5.30	4.70	5.40	6.80
8	5.30	6.30	6.10	6.30	8.30	8.70	8.10	6.30	5.30	4.70	5.50	6.70
9	5.30	6.30	6.00	6.60	8.70	8.80	8.00	6.20	5.30	4.70	5.70	6.60
10	5.30	6.20	6.00	6.80	9.30	9.10	8.00	6.10	5.20	4.80	5.70	6.60
11	5.20	6.20	6.00	6.80	9.20	9.40	8.00	6.10	5.20	4.70	5.80	6.50
12	5.20	6.30	5.90	6.70	9.00	9.80	7.90	6.10	5.20	4.70	5.80	6.40
13	5.20	6.30	5.90	7.40	8.80	10.10	7.90	6.00	5.10	4.70	6.00	6.30
14	5.20	6.50	5.90	7.20	8.70	10.10	8.00	6.00	5.10	4.70	6.20	6.20
15	5.20	6.80	5.80	7.10	8.60	9.90	8.00	6.00	5.10	4.70	6.30	6.10
16	5.30	7.00	5.80	7.00	8.40	9.80	7.90	6.00	5.00	4.70	6.40	6.00
17	5.60	7.30	5.70	6.80	8.20	9.80	7.85	6.00	5.00	4.80	6.40	5.90
18	5.80	7.60	5.70	6.60	8.10	9.80	7.80	6.00	5.00	4.80	6.50	5.70
19	6.10	7.70	5.60	6.40	7.90	9.70	7.80	5.90	5.00	5.00	6.80	5.60
20	6.30	7.90	5.70	6.30	7.70	9.60	7.60	5.90	5.00	5.60	7.60	5.40
21	7.40	7.60	5.60	6.30	7.70	9.50	7.50	5.90	5.00	5.80	8.00	5.40
22	8.00	7.30	5.70	6.20	7.60	9.50	7.50	5.80	5.00	5.70	7.90	5.30
23	8.50	7.10	5.60	6.40	7.70	9.40	7.50	5.80	5.00	5.60	7.60	6.20
24	8.00	6.90	5.60	6.50	8.90	9.10	7.50	5.80	5.00	5.50	7.40	7.00
25	7.70	6.70	5.60	6.70	9.40	9.00	7.50	5.70	5.00	5.50	7.20	9.00
26	8.40	6.60	5.50	6.80	9.40	8.90	7.30	5.70	4.90	5.50	7.00	9.50
27	8.60	6.60	5.50	7.00	9.10	8.70	7.10	5.70	4.90	5.50	7.00	9.20
28	8.40	6.50	5.50	7.10	9.00	8.60	7.05	5.60	4.90	5.60	8.00	8.90
29	8.00	.....	5.60	7.00	8.90	8.40	6.90	5.60	4.90	5.60	9.00	8.10
30	7.80	.....	5.70	7.00	8.90	8.50	6.80	5.60	4.90	5.60	8.70	7.70
31	7.50	.....	5.80	.....	8.80	.....	6.70	5.50	.....	5.50	.....	7.70

YAKIMA RIVER AT KIONA, WASHINGTON.

This station is located on the lower course of the river, at the point where it bends northerly, sweeping around a point of hill to enter Columbia River 23 miles below. The station, established August 20, 1895, is located at the highway bridge at Kiona. The length of the wire gage is 27.21 feet. The channel of the river is straight for some distance above and below. The banks are of medium height and the bed is composed of firm gravel. The bridge crosses the river with one span, and the section is an ideal one for discharge measurements. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 359; 1897, Nineteenth Annual Report, Part IV, page 484; 1898, Twentieth Annual Report, Part IV, page 502. The following discharge measurements were made by Sydney Arnold in 1899:

July 18, gage height, 9.65 feet; discharge, 11,180 second-feet.
August 10, gage height, 6.16 feet; discharge, 3,482 second-feet.
September 7, gage height, 5.31 feet; discharge, 2,107 second-feet.
October 18, gage height, 4.42 feet; discharge, 1,244 second-feet.

Daily gage height, in feet, of Yakima River at Kiona, Washington, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	8.00	8.00	6.83	5.72	7.45	9.65	9.35	7.15	5.25	4.58	5.50	9.76
2	7.85	7.55	6.75	5.78	7.40	9.60	9.20	7.03	5.22	4.57	5.45	10.35
3	7.80	6.80	6.50	5.90	7.25	9.70	9.30	6.90	5.18	4.60	5.38	10.57
4	7.20	6.38	6.50	5.98	7.05	10.20	9.60	6.63	5.18	4.70	5.30	9.75
5	6.80	6.20	6.50	6.05	7.00	11.20	10.00	6.50	5.20	4.68	5.28	9.16
6	5.45	6.10	6.40	6.17	7.30	11.00	9.85	6.35	5.28	4.60	5.25	8.63
7	5.25	6.09	6.40	6.32	7.80	10.45	9.60	6.25	5.30	4.58	5.20	8.12
8	5.35	6.09	6.30	6.40	8.30	10.15	9.45	6.15	5.26	4.52	5.10	.....
9	5.40	6.15	6.35	6.50	.....	9.80	9.35	6.15	5.21	4.50	5.18	7.60
10	5.50	6.26	6.40	6.75	.....	9.90	9.38	6.15	.....	4.48	5.40	7.55
11	5.56	6.95	6.25	7.13	10.35	10.65	9.45	6.15	5.12	4.52	5.65	7.40
12	5.60	6.95	6.10	7.13	10.43	11.10	9.30	6.18	5.05	4.50	5.72	7.28
13	5.54	6.80	6.08	7.90	10.41	11.35	9.18	6.08	4.95	4.48	5.85	6.94
14	5.50	6.56	6.05	8.05	9.90	11.20	9.50	6.03	4.98	4.50	5.95	6.86
15	5.45	6.61	5.90	7.85	9.35	10.70	9.40	6.00	5.03	4.52	6.03	6.71
16	5.45	7.10	5.85	7.68	8.97	10.43	9.55	6.04	5.04	4.48	6.62	6.45
17	5.43	7.73	5.85	7.53	8.75	10.45	9.60	6.10	4.98	4.42	6.79	6.32
18	5.70	8.70	5.73	7.45	.....	10.80	9.60	6.08	4.95	4.48	6.96	6.20
19	6.22	9.23	5.60	7.38	8.40	11.25	9.33	6.00	4.92	4.80	7.25	6.05
20	6.40	8.50	5.60	.....	8.20	11.45	9.10	5.90	4.87	5.05	7.92	5.97
21	6.85	8.48	5.62	7.10	8.15	11.35	8.85	5.78	4.85	5.50	8.40	5.83
22	8.45	8.15	5.63	7.20	8.20	11.10	8.65	5.75	4.78	5.60	8.98	6.22
23	9.55	7.80	5.65	7.30	8.60	10.65	8.18	5.72	4.74	5.62	8.42	7.34
24	9.30	7.50	5.65	7.10	9.15	10.85	7.90	5.70	4.70	5.56	7.85	8.65
25	8.87	7.35	5.65	7.00	10.10	10.20	7.58	5.55	4.67	5.45	7.45	9.78
26	8.80	7.20	5.65	7.10	10.50	10.40	7.38	5.48	4.63	5.47	7.18	10.69
27	9.30	7.05	5.60	7.40	10.55	10.35	7.25	5.50	4.58	5.38	6.98	10.88
28	9.30	6.90	5.60	7.65	10.45	10.15	7.20	5.50	4.58	5.43	7.95	10.50
29	8.95	.....	5.65	7.55	10.30	9.70	7.20	5.45	4.57	5.52	8.46	9.77
30	8.65	.....	5.68	7.45	10.10	9.50	7.20	5.38	4.58	5.56	9.05	9.20
31	8.25	.....	5.70	.....	9.90	.....	7.25	5.32	.....	5.50	.....	8.96

WALLAWALLA RIVER AT WHITMAN, WASHINGTON.

The tributaries of this river drain the northern and western slopes of the Blue Mountains in southeastern Washington. The general course of the stream is westerly, entering Columbia River 2 miles below the mouth of Snake River. The Blue Mountains attain elevations of over 2,000 feet above their foothills, and their slopes are

well timbered. Agriculture is practiced to a considerable extent on the foothill regions in the vicinity of Wallawalla, the crops being raised without irrigation. A number of canals divert water from the river below Whitman and from the lower course of its tributary, Touchet River. To determine the amount of water available for irrigation below, a gaging station was established at Whitman, 7 miles below Wallawalla, July 19, 1897. The gage consists of a horizontal timber fastened to two posts set in the ground and projecting out over the water surface. To this horizontal rod is attached a wire gage. The bench mark is a nail driven into the northwest corner of a barn 70 feet north of the gage and 1 foot above the sill, and is at an elevation of 11 feet above gage datum. The length of gage wire is 19.62 feet. The discharge measurements were to have been made from a bridge, which, however, has not yet been erected. The results of measurements may be found as follows: 1897, Nineteenth Annual Report, Part IV, page 492; 1898, Twentieth Annual Report, Part IV, page 512. There were no discharge measurements made at this point during 1899.

Daily gage height, in feet, of Wallawalla River at Whitman, Washington, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.60	2.45	3.00	3.05	3.30	3.85	2.30	1.45	1.85	1.75	2.10	3.95
2	2.45	2.25	3.05	3.05	3.25	4.00	2.25	1.45	1.85	1.75	2.10	4.55
3	2.30	2.20	2.95	3.15	3.15	3.95	2.15	1.45	1.85	1.75	2.10	3.95
4	2.20	2.20	2.90	3.30	3.10	3.95	2.10	1.45	1.90	1.75	2.10	3.50
5	2.20	2.20	2.85	3.40	3.20	3.75	2.15	1.45	2.05	1.80	2.10	3.35
6	2.20	2.20	2.80	3.30	3.30	3.35	2.05	1.40	1.95	1.80	2.10	3.05
7	2.20	2.20	2.85	3.40	3.35	3.30	2.00	1.40	1.90	1.80	2.10	3.05
8	2.20	2.20	3.10	3.60	3.80	3.15	2.00	1.40	1.95	1.80	2.10	2.90
9	2.20	2.95	3.10	4.15	4.30	3.25	1.95	1.50	1.95	1.80	2.10	2.80
10	2.20	4.20	3.05	4.05	4.50	3.40	1.90	1.55	1.90	1.80	2.10	2.80
11	1.90	3.65	3.00	4.10	4.35	3.95	1.90	1.50	1.95	1.85	2.10	3.00
12	1.95	3.25	2.95	4.50	4.05	3.85	1.90	1.50	1.90	1.90	2.10	3.00
13	1.95	3.30	2.85	4.50	3.90	3.50	1.80	1.50	1.95	1.90	2.10	2.85
14	1.95	3.85	2.75	4.05	3.65	3.35	1.80	1.60	1.95	1.90	2.10	2.80
15	2.15	4.60	2.75	3.95	3.50	3.30	1.70	1.70	1.95	1.90	2.10	2.80
16	2.70	4.40	2.75	4.40	3.40	3.30	1.60	1.65	1.90	1.90	2.15	2.80
17	3.50	4.35	2.75	4.10	3.45	3.30	1.60	1.65	1.85	2.30	2.15	2.80
18	3.45	4.30	2.75	3.85	3.40	3.25	1.60	1.65	1.90	2.20	2.25	2.70
19	3.45	4.45	2.80	3.65	3.25	3.20	1.50	1.65	1.85	2.35	2.70	2.60
20	3.55	4.30	2.95	3.60	3.20	3.15	1.55	1.65	1.85	2.60	2.75	2.55
21	5.00	4.10	3.00	3.75	3.20	3.00	1.50	1.70	1.80	2.40	2.65	2.60
22	5.50	3.60	3.00	3.95	3.50	2.85	1.60	1.90	1.85	2.35	2.55	2.85
23	4.00	3.25	3.00	3.75	3.85	2.75	1.55	1.90	1.85	2.30	2.50	3.10
24	3.30	3.30	3.00	3.70	4.35	2.65	1.55	1.85	1.80	2.25	2.45	3.50
25	3.20	3.10	3.00	3.75	4.55	2.65	1.55	1.85	1.80	2.30	2.30	3.35
26	3.10	2.90	3.00	3.75	4.30	2.65	1.55	1.85	1.80	2.30	2.35	3.20
27	3.00	2.80	3.00	3.70	4.10	2.55	1.55	1.95	1.75	2.25	2.35	3.15
28	2.95	2.85	3.00	3.45	4.05	2.45	1.55	1.95	1.75	2.20	2.90	3.00
29	2.85	.....	3.00	3.25	4.05	2.40	1.45	1.90	1.75	2.20	3.50	2.90
30	2.75	.....	3.00	3.35	3.75	2.35	1.45	1.90	1.75	2.20	3.80	2.80
31	2.65	.....	3.00	.....	3.65	.....	1.45	1.90	.....	2.15	.....	2.80

UMATILLA RIVER AT GIBBON, OREGON.

This river rises in the well-wooded country in northeastern Oregon and flows in a general westerly direction, entering Columbia River below the mouth of Wallawalla River. The country north of Umatilla is high and rolling. Agriculture is practiced here to a consider-

able extent, cereals being the principal crops raised. A number of canals divert water from the lower course of the stream to irrigate lands on either side. Surveys have been made for diverting water in the vicinity of Gibbon to irrigate the high country between Umatilla and Wallawalla rivers. None of the canals have yet been completed, however. The station at Gibbon, Oregon, was established July 22, 1896, and is located one-half mile west of the railroad station. The rod is inclined and is fastened to a rock ledge by bolts soldered into holes drilled into the rock. The bench mark is a cross in black paint on the highest point of the rock to which the rod is fastened, and is 4.40 feet above gage datum. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 361; 1897, Nineteenth Annual Report, Part IV, page 493; 1898, Twentieth Annual Report, Part IV, page 515. There were no measurements of discharge made at this point during 1899.

Daily gage height, in feet, of Umatilla River at Gibbon, Oregon, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.55	2.50	2.40	2.65	2.50	3.85	1.90	1.05	1.00	1.00	1.60	3.20
2	1.45	2.20	2.50	2.70	2.50	3.80	1.80	1.05	1.00	1.00	1.50	2.90
3	1.40	2.00	2.50	2.75	2.50	3.70	1.75	1.05	1.00	1.00	1.45	2.75
4	1.30	1.95	2.40	3.30	2.55	3.50	1.65	1.05	1.10	1.00	1.45	2.60
5	1.30	1.80	2.25	3.30	3.05	3.10	1.65	1.00	1.20	1.00	1.45	2.40
6	1.25	1.75	2.20	3.30	3.80	3.00	1.60	1.00	1.10	1.00	1.40	2.30
7	1.25	2.00	2.40	3.50	4.40	3.00	1.60	.95	1.10	1.00	1.40	2.20
8	1.15	2.70	2.75	3.70	4.40	3.20	1.60	.95	1.10	1.00	1.40	2.20
9	1.10	3.30	2.60	4.30	4.90	3.30	1.55	.95	1.05	1.00	1.40	2.20
10	1.00	3.30	2.30	4.30	4.60	3.50	1.50	1.05	1.05	1.00	1.40	2.20
11	.95	2.90	2.30	4.10	4.40	3.20	1.50	1.05	1.00	1.00	1.40	2.20
12	.90	2.60	2.10	5.00	4.20	3.10	1.45	1.00	1.00	1.00	1.40	2.25
13	.90	2.50	2.10	4.20	4.05	2.95	1.45	1.00	1.05	1.00	1.40	2.20
14	.90	2.80	2.10	3.60	3.50	3.10	1.45	1.00	1.00	1.00	1.45	2.20
15	.90	3.45	2.15	3.60	3.20	3.00	1.40	1.00	1.00	1.00	1.50	2.20
16	1.80	3.30	2.15	3.80	3.10	2.90	1.35	1.00	1.00	1.20	1.50	2.20
17	2.50	3.40	2.20	3.40	3.05	2.90	1.35	1.00	1.00	1.40	1.50	2.15
18	2.90	3.60	2.30	3.20	3.05	2.75	1.35	1.00	1.00	1.40	1.90	2.15
19	2.70	3.90	2.60	3.05	3.00	2.70	1.30	1.00	1.00	1.60	2.10	2.10
20	3.30	3.70	2.50	3.40	2.95	2.60	1.30	1.05	1.00	1.50	2.10	2.10
21	4.50	3.20	2.50	3.40	3.00	2.50	1.30	1.05	1.00	1.50	2.00	2.10
22	4.00	2.80	2.40	3.45	3.80	2.45	1.25	1.35	1.00	1.50	1.80	2.05
23	3.40	2.60	2.20	3.50	4.10	2.40	1.20	1.20	1.00	1.50	1.80	2.00
24	3.00	2.45	2.60	3.50	4.40	2.25	1.20	1.10	1.00	1.60	1.70	2.00
25	2.80	2.40	2.70	3.60	4.30	2.20	1.20	1.10	1.00	1.65	1.70	2.10
26	3.50	2.20	2.60	3.30	4.00	2.10	1.15	1.05	1.00	1.70	1.70	2.20
27	3.30	2.10	2.50	3.20	3.80	2.00	1.15	1.05	1.00	1.70	2.40	2.20
28	3.10	2.40	2.50	3.00	3.80	1.95	1.10	1.05	1.00	1.75	2.70	2.15
29	3.00	.....	2.55	2.75	4.00	1.90	1.10	1.05	1.00	1.70	3.10	2.15
30	2.70	.....	2.50	2.60	4.00	1.90	1.10	1.00	1.00	1.65	3.15	2.15
31	2.60	.....	2.60	.....	3.90	.....	1.10	1.00	.....	1.60	.....	2.10

DESCHUTES RIVER AT MORO, OREGON.

This river drains a large area in central Oregon and flows in a general northerly direction, entering Columbia River about 15 miles east of The Dalles, Oregon. The headwater tributaries have their source in the snow-clad peaks of the Cascade Mountains. The plains region on which they enter upon their appearance from the mountain canyons is of a very porous lava formation, which has a tendency to regulate the flow of the river. The rains and snows of the winter are absorbed

by the porous rocks, to be slowly discharged into the river later in the season. In the vicinity of the town of Lava the river is noted for its unchanging flow, the height not varying, on an average, more than 12 to 18 inches during the year, with a comparatively large discharge. The river is a surface stream until about due west of Prineville, when it gradually cuts down, and on its lower course is in a canyon about 1,000 feet in depth. The lower portion of the river is also subject to greater fluctuations in height than the upper part. The general character of the lower basin of Deschutes River is high and rolling and it is difficult to irrigate, except from the high tributaries. Crooked River is an important tributary of the Deschutes, entering it from the east. Considerable irrigation, principally for forage crops, is practiced in its basin above Prineville. The station on Deschutes River, established October 19, 1897, is located at Moro, 3 miles above what is known as the "free bridge" and 16 miles east of The Dalles, Oregon. The rod is inclined. The bench mark is the head of a nail in a large alder tree, to which the rod is spiked, and is at an elevation of 8.41 feet above gage datum. Discharge measurements are taken at the iron bridge 3 miles below. The section here is poor, owing to its rocky cross section. The current is quite swift. The results of measurements may be found as follows: 1897, Nineteenth Annual Report, Part IV, page 97; 1898, Twentieth Annual Report, Part IV, page 516. One measurement of discharge was made in 1899 by Sydney Arnold, on June 10, when, at a gage height of 3.80 feet, a discharge of 10,772 second-feet was found.

Daily gage height, in feet, of Deschutes River at Moro, Oregon, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	1.70	2.50	5.50	2.70	3.50	4.00	3.30	2.50	2.30	1.90	2.30	3.70
2	1.70	2.40	3.90	2.90	3.40	4.00	3.30	2.50	2.30	2.00	2.30	3.60
3	1.60	2.20	3.30	2.90	3.30	4.00	3.40	2.50	2.30	2.00	2.30	3.50
4	1.60	1.90	3.00	3.00	3.10	3.90	3.40	2.40	2.40	2.00	2.30	3.40
5	1.50	1.70	2.80	3.30	3.10	3.80	3.30	2.40	2.50	1.90	2.30	3.40
6	1.40	1.60	2.70	3.60	3.20	3.80	3.30	2.40	2.50	1.90	2.40	3.30
7	1.40	1.50	2.70	3.70	3.30	3.70	3.30	2.40	2.40	1.90	2.40	3.30
8	1.30	1.40	2.60	3.80	3.70	3.70	3.20	2.40	2.40	1.90	2.40	3.20
9	1.30	3.60	2.60	3.90	4.10	3.60	3.20	2.40	2.40	2.00	2.40	3.20
10	1.20	5.00	2.50	4.10	4.30	3.70	3.20	2.30	2.30	2.00	2.40	3.10
11	1.20	4.00	2.50	4.30	4.30	3.70	3.30	2.30	2.30	2.00	2.30	3.20
12	1.30	3.60	2.60	4.60	4.40	3.80	3.30	2.30	2.30	2.00	2.30	3.30
13	1.30	3.00	2.50	4.70	4.40	3.90	3.30	2.30	2.30	2.10	2.30	3.60
14	1.20	2.80	2.50	4.90	4.20	3.90	3.20	2.20	2.20	2.10	2.30	4.10
15	1.30	2.60	2.40	4.60	4.00	3.80	3.20	2.20	2.20	2.10	2.30	4.10
16	2.90	2.50	2.40	4.30	3.90	3.80	3.10	2.20	2.20	2.10	2.30	3.90
17	2.70	2.50	2.30	4.10	3.80	3.70	3.10	2.20	2.20	2.10	2.30	3.70
18	3.40	2.80	2.30	3.90	3.60	3.80	3.10	2.10	2.20	2.20	2.20	3.60
19	3.20	2.80	2.50	3.70	3.40	3.90	3.00	2.20	2.10	2.50	2.20	3.60
20	3.40	2.90	2.50	3.50	3.40	3.90	3.00	2.10	2.10	3.10	2.20	3.70
21	3.70	2.80	2.40	3.80	3.30	3.80	2.90	2.10	2.10	2.50	2.20	3.90
22	4.10	2.70	2.40	4.00	3.30	3.70	2.80	2.20	2.10	2.30	2.20	3.80
23	3.60	2.70	2.50	4.10	3.40	3.70	2.80	2.40	2.10	2.30	2.20	3.70
24	3.10	2.60	2.50	4.10	3.50	3.60	2.70	2.40	2.00	2.30	2.20	3.60
25	2.80	2.60	2.80	4.00	3.60	3.60	2.70	2.40	2.00	2.30	2.20	3.60
26	2.70	2.50	3.50	3.90	3.70	3.50	2.70	2.50	2.00	2.40	2.30	3.50
27	2.60	2.40	3.30	3.80	3.80	3.50	2.60	2.50	2.00	2.40	3.70	3.40
28	2.40	2.50	2.90	3.70	3.90	3.50	2.60	2.50	1.90	2.40	4.10	3.30
29	2.20	.....	2.90	3.70	3.90	3.40	2.60	2.40	1.90	2.40	4.10	3.20
30	2.30	.....	2.80	3.60	3.90	3.40	2.60	2.40	1.90	2.40	4.10	3.20
31	2.70	.....	2.70	.....	4.00	.....	2.50	2.40	.....	2.40	.....	3.10

A survey of a portion of Deschutes River, from Pringle Falls above the East Fork down to and including the country around Prineville, on Crooked River, and below Warmspring, was made during May and June, 1899, by Mr. G. F. Allardt, civil engineer for the Oregon Irrigation Company. Sufficient information was obtained to locate the general routes of the main irrigating canals and to determine the limits of the country that could be watered. The following details are taken from the report by Mr. Allardt:

Measurements of the river were made on May 27, 1899, at Sizemore bridge, about 1 mile above Emigrant Ford, giving a flow of 3,014 second-feet. At the time of measurement the river was somewhat above its ordinary stage and was 380 feet wide, with an average depth of about 3 feet and a mean velocity of nearly 3 feet per second. At its lowest stage the discharge of the river was estimated, from marks pointed out by the oldest settlers, to amount to 1,740 second-feet. It is stated that the difference between the high- and low-water marks does not exceed 2 feet in the wider portions of the river.

The low banks of the river make possible the diversion of water into canals by means of open cuts from the river channel at points a short distance above the various falls or rapids, thus dispensing with dams. The slight fluctuations in surface level reduce the cost of headworks to a minimum, and as the river never freezes it is unnecessary to adopt precautionary measures against ice.

Five principal canals were surveyed, leading out in succession from the east or right-hand side of the river. The first of these heads at Pringle Falls and has a length of 30 miles; the next heads at Benham Falls, 18 miles below, and has a length of 15 miles; the third heads at Lava Island, 4 miles below, and has a length of 34 miles; the fourth heads at Emigrant Ford, 5 miles below, and has a length of 33 miles; the fifth, or North canal, heads 20 miles below, and has a length of 47 miles, extending to Trout Creek. The following table gives the principal facts concerning the acreage irrigable and the altitude of the lands. Of the total acreage about one-fourth, or 92,000 acres, is timbered:

Proposed canals from Deschutes River.

Name.	Length.	Area irrigable.	Altitude.
	Miles.	*Acres.*	*Feet.*
Pringle Falls canal	30	36,000	4,100–4,300
Benham Falls canal	15	22,000	3,800–4,100
Lava Island canal	34	103,000	3,600–3,800
Emigrant Ford canal	33	168,000	2,900–3,600
North canal	47	58,000	2,400–2,900
Total	159	387,000	

The slope of the irrigable country from south to north is fairly uniform, averaging about 23 feet to the mile. The soil is mainly composed of volcanic ash or finely disintegrated lava, easily cultivated, and when wet of a dark or chocolate color. About one-fourth of the irrigable land is somewhat stony or broken by outcroppings of lava. The rainfall at Prineville averages about 9 inches per annum.

A large amount of power can be created by the use of the surplus waters of the river, as the total fall of the river is 1,360 feet between Pringle Falls and Crooked River. It is estimated that more than 50,000 effective horsepower can be produced by diverting the water by means of short flumes and without the construction of dams.

HOOD RIVER AT TUCKER, OREGON.

This river rises at the base of Mount Hood, which has an elevation of 11,225 feet and is covered with snow throughout the year. The upper part of its basin is mountainous and well wooded. The river itself flows in a very narrow valley throughout its entire course, and empties into Columbia River almost opposite White Salmon River, which enters from the State of Washington. Hood River Valley, so called, is a level, elevated district, extending from the edge of the bluff overlooking Columbia River southward for a distance of from 7 to 10 miles. The river in its 30-mile course has a heavy fall, so that canals diverting water from it can in a short distance attain considerable elevation above the river. A number of canals divert water from East Fork and from the main Hood River, and irrigate the bench land south of the town of Hoodriver. The chief products are berries and fruits. The gaging station, established October 20, 1897, is located at Tucker, 5 miles south of Hoodriver, Oregon. The rod of the wire gage is nailed to a wooden member of the bridge. The length of the gage wire is 33.85 feet. The bottom of the river is a rock ledge and the sides are precipitous, thus insuring a stable cross section. Results of measurements may be found as follows: 1897, Nineteenth Annual Report, Part IV, page 499; 1898, Twentieth Annual Report, Part IV, page 516. One measurement of discharge was made by Sydney Arnold during 1899, on June 9, when at a gage height of 4.55 feet a discharge of 2,548 second-feet was found.

Daily gage height, in feet, of Hood River at Tucker, Oregon, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.20	4.40	7.50	2.80	3.80	4.60	3.80	3.00	2.60	3.20	2.10	9.00
2	4.00	4.00	6.00	2.90	3.60	4.60	3.90	3.00	2.50	2.60	2.10	6.60
3	3.80	3.80	4.80	3.00	3.50	4.50	4.00	2.90	2.50	2.30	2.00	5.60
4	3.60	3.50	4.60	3.50	3.50	4.50	4.10	2.90	2.70	2.30	2.20	4.80
5	3.50	3.60	4.20	3.40	3.40	4.70	4.00	2.90	2.50	2.20	2.20	4.60
6	3.30	3.20	4.00	3.30	3.60	4.10	4.00	2.90	2.60	2.20	2.20	4.20
7	3.00	3.30	4.00	3.20	3.50	4.10	3.90	2.90	2.40	2.10	2.70	3.80
8	2.80	4.10	3.80	3.20	3.70	4.50	3.80	2.80	2.40	2.10	2.60	3.60
9	2.60	6.15	3.80	3.50	4.20	4.70	3.80	2.80	2.40	2.10	2.70	3.20
10	2.40	6.50	3.70	3.50	4.40	4.50	3.80	3.60	2.30	2.10	2.80	3.50
11	2.30	5.50	3.60	4.50	4.90	5.50	3.80	3.00	2.30	2.10	2.80	4.50
12	2.20	4.80	3.50	6.60	4.40	5.20	3.80	2.80	2.40	2.10	2.80	4.20
13	2.10	4.60	3.50	5.50	4.30	5.00	3.90	2.70	2.40	2.00	2.70	4.00
14	2.00	4.40	3.30	4.50	3.90	4.50	4.00	2.60	2.40	1.90	2.70	3.80
15	4.00	5.50	3.70	4.20	3.60	4.50	4.10	2.60	2.30	1.70	2.60	3.60
16	6.30	4.80	3.20	4.50	3.60	4.40	4.10	2.70	2.30	1.80	2.70	3.50
17	6.20	4.50	3.00	4.50	3.60	4.60	4.00	2.70	2.30	2.00	2.70	3.40
18	6.10	4.50	3.00	4.00	3.60	4.80	4.00	2.60	2.30	2.60	2.80	3.40
19	5.80	4.40	3.00	4.00	3.60	5.00	3.90	2.60	2.30	5.10	5.40	3.40
20	7.15	4.30	3.00	3.90	3.50	4.60	3.90	2.60	2.30	4.00	4.50	3.30
21	11.00	4.20	3.00	3.90	3.50	4.20	3.50	2.60	2.30	3.60	4.40	4.80
22	7.50	4.00	3.00	3.90	3.60	4.20	3.40	4.00	2.20	3.00	4.00	4.90
23	6.50	3.90	2.90	5.30	3.70	4.20	3.20	2.90	2.10	2.70	3.80	4.70
24	5.30	3.70	2.90	5.45	3.90	4.20	3.20	2.70	2.10	2.60	3.50	4.70
25	4.90	3.60	2.80	6.00	4.00	4.40	3.20	2.70	2.10	2.50	3.20	4.70
26	5.80	3.50	2.70	5.45	4.00	4.20	3.20	2.80	2.10	2.50	3.30	4.60
27	4.50	4.20	2.70	5.50	4.00	4.20	3.20	3.30	2.20	2.40	6.00	4.40
28	4.20	5.65	2.70	5.30	4.40	3.90	3.30	2.80	2.20	2.30	5.80	4.20
29	4.10	.....	2.70	5.35	4.40	3.90	4.00	2.70	2.20	2.30	7.20	3.80
30	4.10	.....	2.80	3.90	4.40	3.90	3.40	2.60	2.60	2.20	6.60	3.70
31	4.80	.....	2.80	.....	4.00	.....	3.20	2.60	.....	2.20	.....	3.60

WHITE RIVER AT BUCKLEY, WASHINGTON.

This river has its source in the glaciers of Mount Rainier, in the Cascade Range in Washington, and flows in a general northwesterly direction, entering Puget Sound at Seattle. Its mountainous collecting area is densely forested, and owing to the great precipitation on the western slope of the Cascade Mountains the basin has a high run-off. On account of the great fall of the rivers on the western slope of the Cascade Mountains in Washington, there are a number of fine water powers. These have lately been under investigation. In order to determine the amount of power that could be developed on White River, a station was established by Sydney Arnold, April 22, 1899, at the new highway bridge, 500 feet above the Northern Pacific railway bridge, and one-half mile north of the town of Buckley, Washington. The location is in sec. 34, T. 20 N., R. 6 E. of the Willamette meridian. The rod of the wire gage is fastened to the guard rail of the highway bridge. The length of the wire rope is 20 feet. The elevation of the top of the guard rail at the pulley is 19.56 feet above gage datum. The bridge is a clear span of 180 feet, crossing the river a trifle obliquely. The channel is straight for some distance above and below the bridge, but the section is not a very good one, owing to the sudden fall a short distance below. About 300 feet above the bridge is a good section, with fine gravel bottom in calmer water, but in order to utilize it it would be necessary to erect a cable. An examination of the river channel for some distance above and below this point was made, but the present location is about the only one available for accurate results. The following measurements of discharge were made by Sydney Arnold in 1899:

Discharge measurements of White River at Buckley, Washington.

1899.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
June 5	3.15	3,625	August 23	2.50	2,065
June 21	3.37	3,971	September 13	1.78	1,216
July 25	2.37	2,321	September 27	1.55	1,015
August 8	2.05	1,618	October 9	1.45	998

Daily gage height, in feet, of White River at Buckley, Washington, for 1899.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	2.00	2.86	2.80	2.30	2.00	1.67	1.67	5.78
2	.....	1.85	3.05	3.07	2.17	1.93	1.45	1.60	4.08
3	.....	1.78	3.19	3.47	2.05	1.93	1.40	1.55	3.56
4	.....	1.75	3.44	3.30	2.10	1.90	1.40	1.65	3.15
5	.....	1.96	3.08	2.97	2.07	1.80	1.33	1.50	3.05
6	.....	2.13	3.00	2.93	2.08	1.75	1.33	1.45	2.65
7	.....	2.15	2.78	2.90	2.00	1.63	1.30	1.95	2.50
8	.....	2.78	2.82	3.00	2.05	1.63	1.75	1.75	2.37
9	.....	3.17	3.20	2.95	2.05	1.55	1.45	1.93	2.25
10	.....	2.88	3.81	3.05	2.08	1.55	1.45	1.93	2.20
11	.....	2.93	4.31	3.00	1.95	1.70	1.40	1.93	2.45
12	.....	2.70	3.83	3.13	1.85	1.85	1.40	1.80	2.55
13	.....	2.64	3.58	3.15	1.80	1.78	1.33	1.95	2.40
14	.....	2.64	3.15	3.20	2.33	1.65	1.20	2.50	2.40
15	.....	2.35	3.27	3.20	2.27	1.65	1.10	2.63	2.10
16	.....	2.28	3.65	3.33	2.13	1.60	3.10	2.63	1.87
17	.....	2.37	3.85	3.15	2.05	1.60	2.25	2.35	1.85
18	.....	2.56	3.95	2.95	2.05	1.53	1.95	3.40	1.65
19	.....	2.67	3.78	2.90	1.93	1.53	2.90	4.50	1.70
20	.....	2.62	3.56	2.75	1.93	1.57	2.45	3.85	1.95
21	.....	2.70	3.37	2.55	1.85	1.50	2.13	3.35	2.88
22	1.93	2.75	3.23	2.47	2.86	1.43	1.93	2.80	4.00
23	2.10	3.07	3.30	2.45	2.47	1.40	1.75	2.65	5.38
24	1.93	3.32	3.42	2.50	2.15	1.47	1.95	2.40	3.95
25	1.95	3.30	3.28	2.37	2.05	1.60	1.85	2.27	3.33
26	2.05	3.06	3.15	2.45	2.05	1.60	2.23	2.80	3.15
27	2.05	3.05	2.93	2.66	2.10	1.55	2.23	3.10	3.05
28	1.95	2.92	2.90	2.73	1.95	1.45	2.10	4.20	2.55
29	2.00	2.85	2.90	2.60	1.85	1.45	1.90	3.95	2.50
30	2.05	2.78	2.75	2.53	1.80	1.78	1.87	3.80	2.40
31	.....	2.66	.....	2.37	1.80	.....	1.75	.....	2.22

CEDAR RIVER AT VAUGHN BRIDGE, WASHINGTON.

This river is a tributary of White River and has its source on the western slope of the Cascade Mountains. Flowing in a general northwesterly direction, it enters White River a few miles above its mouth. A study of its discharge has been made during several years by T. A. Noble, for the Seattle Power Company, as there are a number of fine water-power privileges along its course. The station was at first established at Clifford bridge, but was moved in July, 1898, to Vaughn bridge, 15 miles above, and about 3,000 feet below the outlet of Cedar Lake. The drainage area at this point is 80 square miles. In order to reduce the gage heights to sea-level datum 990 feet should be added. The channel was changed during the high water of 1898 and 1899, so that all readings at Vaughn bridge after October, 1898, are not absolutely reliable.

Daily gage height, in feet, of Cedar River at Vaughn bridge, Washington, for 1898.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1....	2.24	1.50	1.30	2.01	2.10	2.40	17.....	1.80	1.30	1.20	1.90	3.25	1.70
2....	2.20	1.50	1.30	2.10	2.62	2.35	18.....	1.80	1.30	1.20	1.80	3.31	1.73
3....	2.20	1.50	1.30	1.96	2.41	2.32	19.....	1.90	1.30	1.20	1.80	3.31	1.80
4....	2.20	1.50	1.40	1.84	2.60	2.30	20.....	1.90	1.30	1.30	1.72	3.20	2.30
5....	2.20	1.50	1.30	1.75	2.73	2.30	21.....	1.80	1.30	1.35	1.74	3.10	2.30
6....	2.20	1.50	1.30	1.70	2.80	2.22	22.....	1.70	1.30	1.60	1.74	3.20	1.92
7....	2.10	1.40	1.30	1.63	2.84	2.22	23.....	1.70	1.30	1.70	1.75	2.70	2.27
8....	2.10	1.40	1.30	1.58	2.75	1.99	24.....	1.70	1.30	1.60	1.70	2.57	2.93
9....	2.00	1.40	1.20	1.64	2.63	1.85	25.....	1.60	1.30	1.50	1.70	2.51	3.30
10....	2.00	1.40	1.20	1.69	2.40	1.80	26.....	1.60	1.30	1.60	1.70	2.31	3.70
11....	2.00	1.40	1.20	1.74	2.31	1.80	27.....	1.60	1.30	1.50	1.74	2.50	4.80
12....	1.90	1.40	1.20	1.65	2.30	1.74	28.....	1.60	1.30	1.60	1.85	2.35	5.40
13....	1.90	1.40	1.25	1.80	2.21	1.70	29.....	1.60	1.30	1.71	1.87	2.40	4.60
14....	1.90	1.40	1.20	1.90	2.06	1.70	30.....	1.50	1.30	1.95	1.80	2.43	3.50
15....	1.80	1.40	1.20	1.94	2.13	1.70	31.....	1.50	1.30	.....	2.00	.....	3.40
16....	1.80	1.40	1.20	1.94	2.25	1.70							

DUNGENESS RIVER AT DUNGENESS, WASHINGTON.

This river rises on the eastern slope of the Olympic Mountains and flows in a general northerly direction, entering the strait of Juan de Fuca at the town of Dungeness, Washington, about 15 miles east of Port Angeles. Its mountainous drainage basin is highly picturesque and very heavily timbered. Although this section of the country receives a heavy precipitation, it occurs when least needed, and during the summer season recourse must be had to irrigation. The station originally established—July 5, 1897—was located 9 miles above the mouth of the river. July 29, 1898, it was moved to the bridge 8½ miles below. This bridge crosses the river diagonally, at an angle of about 15°. The length of the wire rope of the gage is 26.04 feet. The results of measurements may be found as follows: 1897, Nineteenth Annual Report, Part IV, page 504; 1898, Twentieth Annual Report, Part IV, page 518. The following measurements of discharge were made by W. J. Ware during 1899:

Discharge measurements of Dungeness River at Dungeness, Washington.

1899.

Date.	Gage height.	Discharge.	Date.	Gage. height.	Discharge.
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
January 31	4.00	440	May 30	4.10	536
February 22	3.80	443	July 5	4.55	627
March 29	2.95	228	August 31	3.35	223
April 28	3.25	258	September 16	3.25	205

Daily gage height, in feet, of Dungeness River at Dungeness, Washington, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.55	3.90	3.60	3.00	3.20	4.25	4.40	4.10	3.35	3.05	3.80	8.10
2	3.45	3.70	3.55	3.00	3.20	4.50	4.45	4.05	3.40	3.05	3.85	7.20
3	3.40	3.55	3.50	3.05	3.20	4.50	4.70	4.00	3.40	3.00	3.90	6.00
4	3.30	3.55	3.50	3.10	3.15	4.45	4.50	3.95	3.40	3.00	3.95	5.00
5	3.20	3.45	3.45	3.20	3.20	4.45	4.60	4.00	3.35	2.95	3.95	4.80
6	3.10	3.40	3.40	3.30	3.25	4.40	4.60	4.00	3.35	3.00	3.95	4.50
7	3.00	3.45	3.55	3.35	3.40	4.40	4.55	3.90	3.35	2.95	3.95	4.35
8	2.95	3.60	3.55	3.40	3.60	4.50	4.50	3.85	3.30	2.95	4.00	4.20
9	3.00	3.60	3.50	3.45	4.55	4.70	4.45	3.80	3.30	2.95	4.20	4.00
10	3.85	3.65	3.50	3.45	4.20	4.80	4.40	3.75	3.35	2.90	5.40	3.90
11	3.55	3.70	3.50	3.45	4.10	4.90	4.35	3.70	3.35	2.90	5.55	3.90
12	3.15	3.70	3.45	4.05	4.00	5.00	4.40	3.60	3.35	2.85	4.90	3.85
13	3.05	3.75	3.40	3.90	3.85	4.65	4.45	3.50	3.30	2.85	5.40	3.85
14	3.30	3.80	3.35	3.80	3.75	4.55	4.45	3.40	3.30	2.80	6.00	3.75
15	3.15	4.20	3.30	3.65	3.70	4.75	4.50	3.30	3.25	2.80	5.50	3.70
16	3.25	4.30	3.20	3.50	3.65	4.90	4.55	3.20	3.20	2.90	5.40	3.65
17	3.40	4.10	3.15	3.45	3.80	5.05	4.55	3.00	3.20	3.00	5.45	3.60
18	4.80	4.00	3.15	3.40	3.75	4.95	4.50	2.80	3.20	3.50	5.35	3.80
19	4.40	4.30	3.10	3.80	3.80	4.85	4.50	2.50	3.15	4.05	7.10	4.00
20	4.80	4.15	3.10	3.30	3.90	4.65	4.40	2.35	3.15	4.50	6.00	4.50
21	5.20	3.80	3.15	3.25	4.00	4.55	4.30	2.40	3.10	4.00	5.75	5.00
22	4.70	3.75	3.10	3.20	4.10	4.55	4.15	2.40	3.10	3.65	5.30	6.25
23	4.65	3.70	3.10	3.20	4.20	4.60	4.00	2.40	3.10	3.40	5.00	6.50
24	4.60	3.60	3.05	3.30	4.50	4.50	4.05	2.40	3.20	3.30	5.50	6.00
25	4.50	3.50	3.00	3.35	4.65	4.50	4.05	2.45	3.20	3.25	6.00	5.60
26	4.40	3.50	2.95	3.40	4.65	4.40	4.10	2.45	3.15	3.40	7.45	5.20
27	4.35	3.55	3.00	3.35	4.45	4.30	4.10	3.40	3.10	3.55	7.55	4.85
28	4.30	3.60	3.00	3.30	4.30	4.30	4.15	3.35	3.10	3.60	7.20	4.65
29	4.20	.....	3.00	3.25	4.20	4.25	4.15	3.30	3.05	3.80	7.20	4.50
30	4.10	.....	3.00	3.20	4.10	4.35	4.20	3.30	3.05	3.85	9.00	4.40
31	4.00	.....	3.00	.....	4.10	.....	4.25	3.35	.....	3.95	.....	4.40

ELWHA RIVER AT MCDONALD, WASHINGTON.

This river rises in the Olympic Mountains and flows northerly, entering the strait of Juan de Fuca. Its upper basin is very heavily wooded, and is almost inaccessible on account of its rugged character and the dense undergrowth that covers the mountain slopes. In the lower course of the river a number of falls occur where power could be advantageously developed, and within the last few years surveys having this object in view have been made.

Morse River drains a small area east of Elwha River. It flows northward, entering the strait of Juan de Fuca 4 miles east of Port Angeles. Plans contemplating the use of this stream for the city supply of Port Angeles are under consideration. The river also furnishes opportunities for the development of water power. Three measurements of the discharge of the river were made by W. J. Ware in 1899. The first, on June 3, showed a discharge of 242 second-feet; the second, on July 6, showed a discharge of 189 second-feet; the third, on September 15, gave a discharge of 62 second-feet.

Indian Creek is a tributary of Elwha River, entering it from the west about one-fourth of a mile below the gaging station. On June 16 it was discharging 45 second-feet.

Little River is another tributary of Elwha River and enters it from the east side about one-fourth of a mile below the bridge at which the gaging station on the main stream is located. On June 16 it was carrying 84 second-feet.

Clallam River drains an area in northwest Washington, entering the strait of Juan de Fuca at the town of East Clallam. On March 22, 1899, its discharge, as measured by W. J. Ware, was found to be 45 second-feet.

The gaging station on Elwha River, established October 8, 1897, is located 9 miles southwest of Port Angeles, at the new county bridge of Clallam County, Washington. The horizontal rod of the wire gage is fastened to the guard rail at the north side of the bridge. The length of the gage wire is 49.26 feet. The bench mark is the top edge of the top side rail on the north side of the bridge at the third upright post from the east end, and is at an elevation of 41.34 feet above datum. The channel is straight for some distance above and below the station. Both banks are high and rocky and will not overflow. The bed of the stream is rocky. The results of measurements may be found as follows: 1897, Nineteenth Annual Report, Part IV, page 506; 1898, Twentieth Annual Report, Part IV, page 521. The following discharge measurements were made by W. J. Ware during 1899:

January 27, gage height, 3.29 feet; discharge, 1,978 second-feet.
March 18, gage height, 2.20 feet; discharge, 674 second feet.
March 31, gage height, 1.75 feet; discharge, 547 second-feet.
April 24, gage height, 2.15 feet; discharge, 727 second-feet.
June 16, gage height, 4.10 feet; discharge, 2,420 second-feet.
July 31, gage height, 3.40 feet; discharge, 1,644 second-feet.
August 30, gage height, 1.95 feet; discharge, 586 second-feet.

Daily gage height, in feet, of Elwha River at McDonald, Washington, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.85	3.00	2.48	1.80	2.00	3.79	3.40	3.16	2.15	2.01	2.09	6.30
2	2.84	2.70	2.44	1.74	1.98	3.50	3.70	3.15	2.16	1.60	1.95	5.58
3	2.70	2.62	2.26	1.63	1.91	3.95	3.90	3.15	1.96	1.58	2.60	4.80
4	2.48	2.51	2.20	1.70	1.90	3.96	4.10	3.00	1.91	1.57	2.56	4.71
5	2.40	2.47	2.18	1.69	2.04	3.55	4.01	2.90	1.94	1.55	2.09	4.35
6	2.24	2.34	2.22	1.72	2.06	3.40	3.90	2.90	1.91	1.56	2.03	3.96
7	2.19	2.32	2.65	1.86	2.24	3.33	3.75	2.85	1.82	1.54	2.96	3.92
8	2.10	2.74	2.85	1.90	3.13	3.72	3.60	2.76	1.76	1.80	2.66	3.66
9	2.20	3.13	2.46	1.84	3.43	3.85	3.66	2.97	1.72	1.69	4.78	3.62
10	2.85	2.67	2.42	2.20	3.42	4.46	3.60	3.30	1.69	1.65	4.73	3.54
11	2.40	2.59	2.34	3.33	3.31	4.52	3.40	2.75	2.00	1.61	5.11	3.80
12	2.28	2.79	2.27	3.58	3.28	3.85	3.60	2.68	2.02	1.50	3.88	3.53
13	2.34	2.87	2.19	3.42	3.19	3.85	3.92	2.60	1.98	1.35	5.58	3.20
14	2.68	3.29	2.16	2.60	3.02	3.65	4.02	2.65	1.95	1.30	5.48	3.19
15	2.40	4.94	1.99	2.48	2.95	3.80	4.15	2.42	1.77	1.31	4.64	2.99
16	2.48	5.00	1.95	2.34	2.90	4.01	4.10	2.60	1.74	1.96	3.98	2.95
17	3.45	3.65	2.00	2.30	2.40	4.46	4.05	2.70	1.72	1.68	3.65	2.96
18	4.52	3.52	2.20	2.25	2.39	4.15	4.10	2.55	1.72	1.80	6.46	2.70
19	3.90	3.46	1.91	2.14	2.45	4.02	3.95	2.49	1.66	3.23	8.83	2.61
20	4.93	3.25	1.85	2.12	2.47	3.77	3.73	2.40	1.65	3.33	5.65	3.16
21	5.00	2.92	1.90	2.08	2.70	3.74	3.64	2.32	1.66	2.62	5.62	5.26
22	4.10	2.80	1.84	2.07	2.74	3.75	3.40	2.35	1.71	2.19	6.31	8.57
23	3.80	2.99	1.83	2.05	2.78	3.80	3.33	2.37	1.66	2.07	5.46	6.45
24	3.45	2.80	1.76	2.10	3.45	3.94	3.42	2.20	1.78	2.00	5.22	5.10
25	3.72	2.69	1.74	2.05	3.54	3.88	3.32	2.20	1.82	1.98	4.87	4.98
26	3.38	2.85	1.62	2.00	3.64	3.75	3.50	2.20	1.80	2.05	8.09	4.50
27	3.29	2.58	1.63	1.97	3.71	3.54	3.56	2.04	1.79	3.35	7.80	4.19
28	3.22	2.55	1.61	2.05	3.29	3.48	3.64	2.01	1.63	3.36	8.38	3.86
29	3.10	.....	1.70	2.08	3.20	3.35	3.74	1.95	1.61	3.00	5.67	3.82
30	2.97	.....	1.78	2.04	3.18	3.32	3.65	1.90	2.35	2.39	10.00	3.79
31	3.80	.....	1.75	.....	3.25	.....	3.39	1.90	.....	2.10	.....	3.69

CALOWA RIVER AT FORKS, WASHINGTON.

This river has its source on the western slopes of the Olympic Mountains, and flows in a general westerly and southerly direction, uniting with the Solduck and Bogachiel rivers, to form Quillayute River, which enters the Pacific Ocean at Lapush, Washington. The gaging station, established November 12, 1897, is located at the county highway bridge in the southwestern part of Clallam County, near Forks, Washington, and is reached by steamer from Port Angeles to Clallam Bay, and thence overland 30 miles by wagon. The horizontal rod of the wire gage is nailed to the railing of the wagon bridge. The banks are high and rocky, and do not overflow. The results of measurements may be found as follows: 1897 and 1898, Twentieth Annual Report, Part IV, page 522. Three measurements of discharge were made by W. J. Ware during 1899. The first, on March 24, at a gage height of 1.65 feet, gave a discharge of 584 second-feet; the second, on June 23, at a gage height of 0.85 foot, showed a discharge of 265 second-feet; the third measurement, on September 12, at a gage height of 0.20 foot, showed a discharge of 81 second-feet.

Daily gage height, in feet, of Calowa River at Forks, Washington, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.85	2.25	5.20	1.40	2.20	1.85	.60	0.00	−.20	.00	1.45	8.25
2	2.00	1.85	3.85	1.05	2.25	1.85	.60	0.05	−.25	.00	1.20	5.20
3	2.70	1.80	3.65	2.45	2.25	1.80	.60	0.00	−.20	.00	2.85	4.40
4	2.85	1.65	3.45	2.25	2.45	1.65	.60	0.00	−.05	− .05	2.20	4.65
5	2.80	1.65	3.60	2.20	2.20	1.60	.60	− .05	.00	− .20	2.05	4.85
6	2.60	1.85	3.05	2.20	2.20	1.45	.45	− .20	−.05	− .05	2.20	4.85
7	2.20	2.00	5.60	2.05	2.20	1.40	.45	− .05	−.25	− .05	2.40	4.80
8	2.05	2.45	5.00	2.05	3.00	1.25	.45	.00	−.25	.00	2.60	4.65
9	2.85	3.65	5.20	2.65	2.25	1.25	.45	.00	−.20	.05	5.05	4.45
10	7.45	3.00	5.00	2.05	3.00	1.45	.40	.05	−.20	.05	4.85	4.40
11	5.25	3.20	3.85	7.60	2.85	1.65	.40	.20	−.25	.00	5.00	4.25
12	5.00	4.00	3.45	5.40	2.25	1.60	.25	.05	−.20	− .05	4.60	4.20
13	4.85	4.60	3.05	4.30	2.20	1.40	.20	.20	−.25	− .20	4.45	4.20
14	5.40	7.05	2.85	3.45	2.20	1.20	.20	.05	−.25	− .20	5.05	4.20
15	6.80	7.60	2.60	3.60	2.20	1.20	.25	.00	−.25	+ .05	5.00	3.25
16	6.00	6.05	2.40	3.45	2.25	1.20	.25	.05	−.25	1.80	4.25	2.45
17	8.00	6.85	2.05	3.20	2.25	1.20	.20	.05	−.40	1.05	3.65	2.60
18	8.45	6.60	2.00	3.20	2.20	1.05	.20	.00	−.40	.80	11.40	2.40
19	9.00	6.00	1.85	3.40	2.20	1.00	.20	.00	−.40	3.85	8.20	2.25
20	10.80	4.00	1.85	2.80	2.20	.80	.25	− .05	−.45	4.45	8.25	4.25
21	8.00	3.80	1.80	2.45	2.05	.85	.20	− .15	−.60	2.65	8.45	7.85
22	6.80	3.20	1.80	2.40	2.05	.80	.20	− .05	−.60	2.05	8.05	14.60
23	5.00	3.05	1.85	2.20	2.00	.85	.05	− .20	−.60	1.65	8.25	7.85
24	4.00	3.20	1.65	2.20	1.85	.85	.05	− .20	−.60	2.25	6.25	6.00
25	4.25	3.60	1.60	2.25	1.85	.85	.00	− .25	−.45	1.80	5.05	5.60
26	4.00	5.20	1.60	2.80	1.85	1.40	.00	− .25	−.40	1.60	6.45	4.45
27	3.60	5.00	1.45	2.60	2.25	1.00	.00	− .25	−.45	4.20	7.25	4.40
28	3.00	5.60	1.45	2.20	2.05	.85	−.05	− .25	−.65	3.80	6.65	4.40
29	2.85	.....	1.45	2.45	2.00	.80	−.05	− .25	−.20	−3.60	5.00	4.25
30	2.45	.....	1.45	2.00	1.85	.65	−.20	− .25	.25	2.20	13.00	4.25
31	2.40	.....	1.45	.....	1.85	.....	−.05	− .20	.....	1.85	.....	4.20

SOLDUCK RIVER AT QUILLAYUTE, WASHINGTON.

This river has its source on the high western slope of the Olympic Mountains, and drains the country immediately north of the Calowa, joining it, as noted above, to form Quillayute River. The drainage

basin is very heavily wooded, the greater portion of it being included in the Olympic Forest Reserve. The station, established November 13, 1897, is located at the county highway bridge 9 miles northeast of Lapush, near Quillayute, Washington. The horizontal rod of the wire gage is fastened to the rail of the wagon bridge. The channel is straight for some distance above and below the station. The banks are high and rocky and do not overflow. The bed of the stream is composed of rock and gravel and is not liable to change. The results of measurements for 1897 and 1898 may be found in the Twentieth Annual Report, Part IV, page 523. Three measurements of discharge were made by W. J. Ware in 1899: The first, on March 24, at a gage height of 3.15 feet, showed a discharge of 1,023 second-feet; the second, on June 23, at a gage height of 3.20 feet, gave a discharge of 800 second-feet; the third, on September 12, at a gage height of 1.55 feet, gave a discharge of 297 second-feet.

Daily gage height, in feet, of Solduck River at Quillayute, Washington, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.20	4.35	5.00	2.75	3.60	3.30	2.85	2.50	1.70	1.70	2.95	9.45
2	3.95	4.10	4.90	2.75	3.40	3.65	2.95	2.40	1.65	1.80	2.80	7.65
3	3.70	3.90	4.65	2.90	3.35	3.60	3.45	2.30	1.65	1.70	2.70	6.60
4	3.55	3.75	4.55	3.20	3.30	3.35	3.20	2.25	1.70	1.60	3.20	6.45
5	3.40	3.65	4.35	3.10	3.25	3.30	3.05	2.20	1.70	1.50	3.20	6.30
6	3.35	3.55	4.25	3.05	3.25	3.50	2.95	2.30	1.65	1.50	3.25	6.10
7	3.30	3.60	5.05	3.00	3.30	3.30	2.90	2.30	1.65	1.55	3.30	5.95
8	3.25	3.65	5.70	2.95	3.50	3.20	2.90	2.25	1.60	1.55	3.55	5.85
9	3.25	4.05	5.10	3.20	4.45	3.40	2.85	2.35	1.60	1.50	3.45	5.70
10	5.45	4.50	4.90	4.05	4.00	3.80	2.85	2.50	1.55	1.55	5.40	5.55
11	5.25	4.25	4.60	5.10	5.05	3.85	2.85	2.55	1.55	1.55	5.30	7.05
12	4.75	4.75	4.55	7.80	4.45	3.80	2.80	2.45	1.55	1.50	5.10	6.40
13	4.50	5.35	4.45	5.40	4.05	3.85	2.90	2.30	1.50	1.50	4.55	5.70
14	5.60	6.70	4.25	4.75	3.80	3.35	3.00	2.35	1.45	1.45	6.50	5.40
15	6.00	9.30	3.95	4.25	3.60	3.30	3.00	2.30	1.45	1.55	5.70	4.90
16	6.35	6.95	3.75	4.35	3.65	3.45	3.05	2.10	1.40	1.80	5.35	4.60
17	6.85	7.50	3.60	4.25	3.70	3.75	3.00	2.15	1.45	2.10	6.30	4.50
18	9.70	6.40	3.50	4.15	3.50	3.60	2.95	2.20	1.45	2.35	8.20	4.20
19	7.65	6.00	3.40	4.10	3.40	3.45	2.90	2.05	1.40	2.80	12.70	4.25
20	8.80	5.50	3.35	4.00	3.35	3.35	2.85	2.00	1.40	3.45	9.60	4.35
21	8.75	5.20	3.25	4.05	3.35	3.20	2.65	1.95	1.40	4.20	8.45	9.30
22	6.85	4.95	3.25	4.05	3.40	3.15	2.60	1.90	1.35	3.65	7.80	9.50
23	6.10	4.65	3.20	3.80	3.40	3.20	2.60	1.90	1.35	3.00	7.50	11.20
24	5.80	4.55	3.10	3.70	3.80	3.20	2.55	1.85	1.35	3.00	7.40	9.35
25	5.60	4.45	3.05	3.65	3.90	3.20	2.60	1.85	1.35	2.95	7.15	7.90
26	5.40	4.50	3.00	3.60	3.80	3.20	2.70	1.80	1.35	2.95	7.10	6.40
27	5.05	5.30	2.90	3.65	3.85	3.35	2.70	1.80	1.35	4.10	7.05	5.70
28	4.80	5.10	2.85	3.65	3.75	3.10	2.75	1.75	1.35	5.00	9.40	5.65
29	4.45	.....	2.85	3.70	3.50	3.00	2.80	1.75	1.30	4.30	7.65	5.60
30	4.50	.....	2.80	3.75	3.35	2.90	2.70	1.75	1.55	3.45	10.30	5.80
31	4.65	.....	2.75	.....	3.30	.....	2.60	1.70	.....	3.00	.....	5.60

SACRAMENTO RIVER AT JELLYS FERRY, CALIFORNIA.

This river rises in the extreme northeastern corner of California and flows in a general southerly direction, draining the large area in northern California between the Coast Range on the west and the Sierra Nevada on the east. It discharges into San Francisco Bay. A number of storage reservoirs have been constructed on the various tributaries of the river, and are used principally for hydraulic mining purposes and to a less extent for irrigation. The gaging station,

established April 30, 1895, is located 12 miles above the town of Redbluff, at the crossing of the county road at Jellys Ferry. The gage consists of a vertical rod made in three sections and nailed firmly to trees near the ferry landing. A second rod is located 1,206 feet above the gage, and a third one 350 feet below the main rod, in order to determine the slope of the water surface. The three rods are referred to the same datum. Bench mark No. 1 is on an oak tree on the left bank, 1,200 feet above the ferry and 65 feet north of the upper rod, and is 22.724 feet above gage datum. Bench mark No. 2 is on an oak tree on the left bank of the river, 300 feet below the cable, and is 22.429 feet above gage datum. The ferry cable is used in the discharge measurements. The channel for 1,000 feet above and below the station is nearly straight. The right bank is high, but the left bank is liable to overflow when the water rises above the 25-foot mark. The bed of the stream consists of gravel and changes only slightly. Results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 367; 1897, Nineteenth Annual Report, Part IV, page 509; 1898, Twentieth Annual Report, Part IV, page 527. The following measurements of discharge were made under the direction of J. B. Lippincott:

Discharge measurements of Sacramento River at Jellys Ferry, California.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1898.			1899.		
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
December 28	5.3	4,462	April 28	7.3	7,813
1899.			May 13	6.65	7,630
			June 3	6.9	8,409
			June 13	6.9	6,104
January 14	11.4	21,211	June 28	5.5	4,866
January 28	7.5	10,299	July 13	5.25	4,276
February 13	5.9	5,848	July 28	5.05	4,025
February 28	6.1	6,380	August 13	5.0	3,969
March 13	6.15	6,644	August 28	5.0	3,764
March 29	11.5	21,985	September 13	5.0	4,087
April 13	7.8	10,659	September 28	5.0	4,009

Daily gage height, in feet, of Sacramento River at Jellys Ferry, California, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	5.55	7.05	8.40	9.50	6.60	9.20	5.40	5.10	5.00	5.00	5.50	11.20
2	6.10	6.85	8.70	9.30	6.60	7.30	5.40	5.00	5.00	5.00	5.40	9.70
3	6.20	6.70	8.00	8.90	6.50	6.90	5.40	5.00	5.00	5.00	5.40	8.90
4	5.75	6.40	7.50	8.80	6.50	6.70	5.40	5.00	5.00	5.00	5.40	8.30
5	5.65	6.15	7.30	8.70	6.50	6.60	5.40	5.00	5.00	5.00	5.40	8.70
6	5.60	6.00	7.10	8.50	6.50	6.50	5.40	5.00	5.00	5.00	5.40	7.90
7	6.00	6.00	7.00	8.30	6.50	6.30	5.30	5.00	5.00	5.00	5.40	7.60
8	5.95	6.00	6.90	8.40	6.60	6.20	5.30	5.00	5.00	5.00	5.40	7.90
9	5.90	5.90	6.70	8.30	6.50	6.10	5.30	5.00	5.00	5.00	6.40	7.50
10	13.65	5.90	6.60	8.30	6.50	6.10	5.30	5.00	5.00	5.00	10.80	7.40
11	10.05	5.90	6.50	8.10	6.60	6.00	5.30	5.00	5.00	5.00	14.50	8.70
12	7.75	5.90	6.40	8.00	6.60	6.00	5.30	5.00	5.00	5.00	8.20	10.20
13	7.15	5.90	6.30	7.80	6.60	5.90	5.30	5.00	5.00	5.10	7.60	9.00
14	10.90	6.00	6.30	7.70	6.60	5.80	5.30	5.00	5.00	5.10	7.60	8.70
15	16.20	6.00	8.80	7.60	6.50	5.70	5.20	5.00	5.00	5.10	7.00	16.80
16	16.00	6.15	18.95	7.60	6.40	5.70	5.20	5.00	5.00	5.10	7.70	12.40
17	11.05	6.15	12.90	7.50	6.30	5.60	5.20	5.00	5.00	5.00	11.10	11.70
18	13.10	6.20	10.00	7.40	6.30	5.60	5.20	5.00	5.00	5.10	8.70	10.00
19	10.70	6.40	8.80	7.20	6.30	5.50	5.20	5.00	5.00	5.10	9.00	8.90
20	8.85	6.60	8.60	7.20	6.30	5.50	5.20	5.00	5.00	7.65	7.60	8.30
21	8.25	6.70	8.70	7.20	6.20	5.50	5.20	5.00	5.00	7.60	9.10	8.10
22	7.95	6.30	9.70	7.00	6.00	5.50	5.20	5.00	5.00	7.30	9.40	7.80
23	7.65	6.50	14.80	7.00	6.10	5.50	5.10	5.00	5.00	6.90	8.20	7.70
24	7.35	6.50	20.40	7.00	6.10	5.50	5.10	5.00	5.00	6.90	7.60	7.70
25	7.15	6.40	23.00	7.00	6.20	5.60	5.10	5.00	5.00	5.70	7.40	7.40
26	7.15	6.30	16.50	6.90	6.20	5.60	5.10	5.00	5.00	5.60	7.10	7.40
27	7.35	6.10	13.90	6.80	6.20	5.50	5.10	5.00	5.00	5.60	8.20	7.30
28	7.50	6.10	12.40	6.80	6.10	5.50	5.10	5.00	5.00	5.50	17.80	7.20
29	7.55	.....	11.40	6.70	6.10	5.50	5.10	5.00	5.00	5.50	18.20	7.10
30	7.45	.....	10.40	6.70	6.10	5.50	5.10	5.00	5.00	5.40	14.60	8.90
31	7.15	.....	9.80	.....	6.00	.....	5.10	5.00	.....	5.60	.....	8.50

SAN MATEO CREEK, CALIFORNIA.

San Francisco obtains its domestic water supply from a series of impounding reservoirs located in the southern portion of the peninsula between San Francisco Bay and the Pacific Ocean. The drainage basin of these reservoirs ranges in elevation from 250 to 1,800 feet, with an average of about 750 feet. The hills are undulating. There is a limited growth of timber on the northern slopes near the summit, but a large amount of brush covers other portions of the basin. On the southern slopes and crests the hills are frequently bare of brush, but are covered with grasses. The Spring Valley Water Company owns the entire area of the drainage basin and protects the forest covering, not even permitting grazing within its limits. Mr. Herman Schussler, chief engineer of the water company, has furnished this office with a statement of the rainfall and run-off of the drainage basins which contribute to the water supply under the control of the company. The table given below extends from 1869 to the present date, and shows the seasonal rainfall, together with the percentage collected in the reservoirs. The record is, therefore, thirty years in length, and is by far the oldest table of run-off in the State, thus making it of unusual value. The seasonal year, rather than the calendar, is given. Column No. 1 shows the year; column No. 2 the inches of rainfall in the respective basins; column No. 3 the percentage of this rainfall which is caught and delivered, the evaporation being deducted. The portion of the discharge table marked "Southeasterly

portion of the watershed southeast of old dam," etc., refers to the area above the reservoir, which was constructed at an early date. At a later period, at a point lower down the stream, the Crystal Springs dam was constructed and flooded water over the top of the original dam and into the valleys of other streams. This explains the change in the description of the drainage basin which occurs in 1888. The portion of the table marked "Above southeasterly and northeasterly portion of peninsula watershed, total Crystal Lake drainage," is for the entire area above the Crystal Springs gage datum. The remarkable variation in percentage strikingly illustrates the necessity for storing water from the drainage basins in order to provide for periods of drought. In the western portion of the drainage basin there was practically no run-off in the season of 1876–77, and in the easterly portion of the basin there was practically no run-off in the seasons of 1881–82, 1882–83, and 1897–98. It would therefore be necessary to store enough water in the reservoirs to furnish a supply for two summers and at least one winter. Another feature of interest in this table is that while the run-off in the seasons of 1881–82 and 1882–83 was practically nothing from the easterly portion of the basin, the percentage of rainfall in the western portion of the watershed was 29.4 and 23, respectively.

Rainfall and run-off from basin of San Mateo Creek, California.

Year.	Rainfall.	Run-off.	Year.	Rainfall.	Run-off.
Western portion of peninsula watershed:	*Inches.*	*Per cent.*	Southeasterly portion of peninsula watershed (southeast from old dam):	*Inches.*	*Per cent.*
1869–70	41.95	22.6	1877–78	57.7	29.3
1870–71	34.70	9.8	1878–79	43.12	12.2
1871–72	80.42	31.4	1879–80	48.01	15.1
1872–73	39.31	28.4	1880–81	38.78	34.1
1873–74	48.88	29.5	1881–82	25.02	.9
1874–75	44.26	21.2	1882–83	23.06	.0
1875–76	69.24	39.2	1883–84	40.32	26.8
1876–77	23.83	.7	1884–85	25.67	13.1
1877–78	72.51	37.8	1885–86	35.56	25.4
1878–79	56.10	29.2	1886–87	28.61	9.7
1879–80	56.14	35.0	1887–88	32.96	5.3
1880–81	53.81	43.0	1888–89	35.70	7.4
1881–82	34.23	29.4			
1882–83	33.89	23.0	Total	434.53	179.5
1883–84	54.99	33.2	Mean	36.21	14.94
1884–85	38.25	30.0			
1885–86	51.90	43.9	Above southeasterly and northeasterly portions of peninsula watershed, total Crystal Lake drainage:		
1886–87	34.44	29.1			
1887–88	37.53	29.2			
1888–89	41.17	28.1			
1889–90	73.67	44.7	1889–90	72.68	53.2
1890–91	37.69	22.8	1890–91	31.92	24.4
1891–92	43.10	13.3	1891–92	24.16	8.0
1892–93	58.25	24.4	1892–93	47.07	34.3
1893–94	54.90	21.8	1893–94	33.08	29.0
1894–95	66.93	25.2	1894–95	55.77	33.6
1895–96	49.45	21.0	1895–96	32.62	16.2
1896–97	50.47	34.0	1896–97	35.62	19.3
1897–98	26.26	9.6	1897–98	18.17	0.0
1898–99	42.56	17.7	1898–99	30.37	11.0
Total	1,450.83	808.2	Total	381.46	230.1
Mean	48.36	26.94	Mean	38.15	23.01

STANISLAUS RIVER AT OAKDALE, CALIFORNIA.

This river has its source on the western slope of the Sierras Nevada in California. It drains a country between the basins of Mokelumne River on the north and Tuolumne River on the south, and flows in a general southwesterly direction, entering San Joaquin River 23 miles above Stockton. A number of canals divert water from this stream, on either side, the principal one being the canal of the Stanislaus and San Joaquin Water Company, which irrigates lands in the vicinity of Oakdale and between Knights Ferry and Stockton. The present location of the station is 1,000 feet below the railroad bridge and one-half mile north of the town of Oakdale, California. The station as first established, May 3, 1895, was at the railroad bridge, but on July 30, 1898, a cable was stretched across the river at the present location, at J. W. Bell's ranch house. The channel of the river is straight for some distance above and below the station, but the bed is of sand and liable to shift at times of sudden change in the volume of the river. On this account numerous discharge measurements will have to be made each year in order to construct an accurate rating curve for the station.

The canal of the Stanislaus and San Joaquin Water Company diverts water from Stanislaus River at a point 3 miles above Knights Ferry, or approximately 15 miles above Oakdale. The volume of this canal at what is known as Section 3 was rated on June 1, 1898, by turning in various amounts of water and measuring the same with a meter. It was found on June 6, 1899, that silt had accumulated in the bottom of the flume at the old gage, and a new station was adopted. This point was rated similarly to the one of the year previous. The superintendent for the canal company, James Y. Beveridge, kindly reports the depths of water at this station, and from the rating tables discharges are computed. The observations on the gage rod are accurate, but during the spring and fall, when the amount of water which is used for irrigation is not important, it is difficult to obtain accurate reports, because it is of no particular interest to the canal company to record them. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 371; 1897, Nineteenth Annual Report, Part IV, page 511; 1898, Twentieth Annual Report, Part IV, page 530. The following measurements of discharge of the Stanislaus and San Joaquin Water Company's canal were made under the direction of Mr. J. B. Lippincott during 1899:

[1] May 19, gage height, 0.45 foot; discharge, 73.5 second-feet.
June 6, gage height, 2.37 feet; discharge, 71.40 second-feet.
June 6, gage height, 2.95 feet; discharge, 52.28 second-feet.
June 6, gage height, 3.64 feet; discharge, 30.60 second-feet.
June 6, gage height, 4.85 feet; discharge, 0.00 second-feet.

[1] Measurement made at old station; new rod read 2.28.

Estimated daily discharge of Stanislaus and San Joaquin Water Company's canal for 1899.

Day.	Apr.	May.	June.	July.	Day.	Apr.	May.	June.	July.
1	32	65	69	49	17	66	75	72	57
2	36	62	71	41	18	67	76	68	57
3	0	62	70	33	19	69	74	69	57
4	0	62	70	34	20	71	74	69	54
5	69	62	71	32	21	75	73	67	57
6	0	69	71	41	22	76	76	65	58
7	0	69	72	39	23	73	76	65	57
8	15	72	72	41	24	73	75	64	55
9	36	74	72	43	25	71	74	56	54
10	51	75	73	41	26	67	72	51	47
11	62	74	73	46	27	67	69	50	61
12	65	73	0	62	28	67	67	48	57
13	66	74	65	62	29	67	69	48	0
14	65	72	67	55	30	67	69	53	55
15	61	71	73	52	31	.....	66	.....	53
16	64	73	68	46					

Measurements of Stanislaus River at Oakdale, California.

1899.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
March 3	5.13	487	June 28	6.3	1,167
April 20	8.8	3,873	August 3	4.53	143
May 18	7.68	2,634	September 9	4.41	88
June 5	7.94	3,057	December 6	5.41	531
June 18	8.42	3,599			

Daily gage height, in feet, of Stanislaus River at Oakdale, California, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.30	5.00	5.20	7.60	6.60	7.50	6.00	4.60	4.40	4.50	5.00	5.60
2	4.80	5.00	5.10	7.40	6.50	7.60	6.10	4.50	4.40	4.50	4.80	5.60
3	5.60	4.80	5.10	7.20	6.60	7.60	6.00	4.50	4.50	4.40	4.80	5.70
4	4.80	4.80	5.00	7.20	6.50	7.70	5.90	4.50	4.40	4.40	4.60	5.60
5	4.60	4.60	5.00	7.80	6.60	7.60	5.80	4.60	4.40	4.40	4.50	5.40
6	4.50	4.50	4.80	7.80	6.70	8.40	5.60	4.60	4.50	4.40	4.60	5.50
7	4.50	4.50	4.80	8.70	6.80	8.20	5.60	4.80	4.40	4.50	4.40	5.40
8	4.40	4.60	4.70	8.80	7.00	8.50	5.60	4.80	4.40	4.40	4.40	5.40
9	4.40	4.60	4.80	9.60	7.60	8.20	5.50	4.70	4.40	4.50	5.20	5.30
10	5.10	4.60	5.00	9.80	8.00	8.30	5.50	4.60	4.30	4.50	6.40	5.40
11	6.25	4.70	4.80	9.00	9.20	8.50	5.50	4.60	4.40	4.50	7.20	5.40
12	5.40	4.70	4.80	9.00	10.20	9.30	5.40	4.60	4.50	4.50	7.00	5.80
13	5.00	4.70	4.80	8.80	10.00	8.60	5.40	4.60	4.50	4.60	6.80	7.80
14	4.80	4.80	5.00	9.00	9.20	8.30	5.30	4.50	4.40	5.00	6.40	6.00
15	5.00	4.80	5.50	8.80	8.60	8.20	5.10	4.60	4.40	5.00	6.40	7.00
16	4.80	4.70	6.90	9.60	8.60	8.00	5.10	4.50	4.40	4.80	7.40	9.60
17	4.80	4.80	6.00	9.60	8 20	8.40	5.00	4.50	4.40	4.50	7.00	8.80
18	5.00	5.00	5.60	9.10	7.80	8.50	4.90	4.50	4.30	4.40	7.00	8.40
19	5.20	5.30	5.40	8.80	7.40	8.20	4.80	4.50	4.30	4.40	6.80	7.50
20	5.20	5.50	7.80	8.80	7.20	7.60	4.60	4.50	4.30	4.60	6.60	7.00
21	5.50	5.50	6.10	8.90	7.30	7.10	4.60	4.50	4.30	4.80	6.20	6.80
22	5.50	5.40	5.90	9.10	7.50	7.00	4.70	4.50	4.30	5.80	7.00	6.50
23	5.40	5.40	11.10	8.80	7.70	6.90	4.80	4.60	4.20	6.20	6.60	6.30
24	5.40	5.30	13.30	8.60	7.50	6.90	4.80	4.70	4.30	6.00	6.20	6.20
25	5.50	5.20	16.60	8.20	7.10	6.60	4.70	4.40	4.30	5.60	5.80	6.20
26	5.50	5.20	11.70	7.60	6.80	6.60	4.70	4.40	4.20	5.40	6.00	6.00
27	5.50	5.20	10.00	7.40	6.80	6.40	4.70	4.40	4.20	5.20	6.00	6.00
28	5.60	5.20	10.30	7.00	6.80	6.40	4.60	4.40	4.30	5.00	5.80	6.20
29	5.40	.....	9.00	7.00	6.80	6.10	4.70	4.40	4.40	4.80	5.70	6.00
30	5.20	.....	8.60	6.50	7.00	6.00	4.70	4.50	4.40	5.00	5.80	6.40
31	5.20	.....	8.00	.....	7.00	.....	4.60	4.40	.....	4.80	.....	6.80

TUOLUMNE RIVER AT LAGRANGE, CALIFORNIA.

This river rises on the western slope of the Sierras Nevada in California, and drains the country located between Stanislaus River on the north and Merced River on the south. The northern half of the Yosemite National Park includes a portion of the drainage basin of this stream. The river is fed largely from small mountain lakes occurring high in the drainage basin, where the snow remains on the mountain slopes throughout the year, thus insuring a large run-off. The stream has a heavy fall, and the opportunities for power development are numerous. There are also a number of reservoir sites in the basin where water could be stored during the irrigation season. The station, established August 29, 1895, is located at the wagon bridge in the town of Lagrange, California. The rod is vertical and bolted to the right-hand pier of the bridge. The bench mark is a nail driven into the bottom of the west post of the fifth bent south of the south iron cylinder, and is 15.31 feet above gage datum. The station is located below the high dam of the Turlock and Modesto irrigation districts, and also below the head of the canal of the Lagrange Hydraulic Mining Company. This latter canal diverts water from the left bank of the river 3 miles above Lagrange dam. During 1898 water was first turned down the Turlock canal in small quantity, and was used for puddling the banks and testing dams of certain reservoirs. Whenever measurements at the gaging station were made, the Turlock canal and the mining company's canal were also measured. The channel at the station, both above and below the bridge, is straight for several hundred feet, and the velocity of the stream is quite uniform. Both banks are high and not subject to overflow. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 381; 1897, Nineteenth Annual Report, Part IV, page 513; 1898, Twentieth Annual Report, Part IV, page 532. The following measurements were made under the direction of J. B. Lippincott during 1899:

Discharge measurements of Turlock canal for 1899.

April 20, discharge, 10 second-feet.
April 21, discharge, 10 second-feet.
May 19, discharge, 61 second-feet.
June 6, discharge, 10 second-feet.
June 29, discharge, 18 second-feet.
August 3, discharge, 85 second-feet.
September 11, discharge, 29 second-feet.

Estimated daily discharge of Turlock canal for 1899. a

Day.	July.	Aug.	Sept.	Oct.	Nov.	Day.	July.	Aug.	Sept.	Oct.	Nov.
1	5	80	34	10	3	17	10	85	10	10	0
2	5	80	34	10	3	18	48	85	10	1	0
3	5	80	34	10	3	19	48	85	10	1	0
4	5	80	34	10	3	20	48	86	10	1	0
5	5	80	34	10	3	21	10	86	10	1	0
6	5	80	34	10	3	22	5	86	10	3	0
7	5	1	34	10	3	23	8	10	10	3	0
8	5	20	34	10	3	24	8	8	10	3	0
9	10	20	34	10	3	25	1	8	10	3	0
10	10	85	34	10	3	26	1	8	10	3	0
11	10	85	34	10	3	27	1	10	10	3	0
12	10	85	8	10	1	28	1	10	10	3	0
13	10	85	8	10	1	29	1	10	10	3	0
14	10	85	8	10	0	30	8	10	10	3	0
15	10	85	10	10	0	31	28	10	.....	3	.....
16	10	85	10	10	0						

a The quantities are not included in volumes discharged at the Lagrange bridge. There was no flow during the months of January to June, inclusive, nor during December.

Discharge measurements of Lagrange Hydraulic and Mining Company's canal for 1899.

April 20, discharge, 23.5 second-feet.
April 21, discharge, 23.5 second-feet.
May 19, discharge, 24 second-feet.
June 6, discharge, 24 second-feet.
June 29, discharge, 24 second-feet.
August 3, discharge, 24 second-feet.
September 11, discharge, 24 second-feet.

Discharge measurements of Tuolumne River at Lagrange, California, for 1899.

March 3, gage height, 5 feet; discharge, 774 second-feet.
April 20, gage height, 7.55 feet; discharge, 5,712 second-feet.
April 21, gage height, 7.85 feet; discharge, 6,943 second-feet.
May 19, gage height, 6.72 feet; discharge, 3,616 second-feet.
June 6, gage height, 8.47 feet; discharge, 8,964 second-feet.
June 29, gage height, 6.15 feet; discharge, 2,347 second-feet.
August 3, gage height, 3.70 feet; discharge, 23 second-feet.
September 11, gage height, 3.58 feet; discharge, 12 second-feet.

Daily gage height, in feet, of Tuolumne River at Lagrange, California, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.10	4.77	5.00	6.60	6.10	7.10	6.20	4.40	3.80	3.70	5.30	5.60
2	4.30	4.75	5.00	6.50	6.00	6.90	6.10	4.30	3.80	3.65	5.00	5.50
3	4.60	4.70	5.00	6.60	6.00	6.80	6.00	4.20	3.70	3.60	4.90	5.40
4	4.30	4.70	4.90	6.40	6.00	7.20	6.00	4.20	3.70	3.60	4.90	5.40
5	4.27	4.65	4.90	6.90	6.30	8.10	5.90	4.10	3.70	3.55	4.90	5.30
6	4.20	4.60	4.90	7.10	6.10	8.50	5.80	4.00	3.70	3.55	4.90	5.20
7	4.22	4.62	5.10	7.40	6.10	8.50	5.70	4.00	3.70	3.55	5.10	5.20
8	4.35	4.62	5.20	7.60	6.40	8.40	5.60	4.50	3.70	3.50	5.60	5.20
9	4.32	4.63	5.30	7.90	6.90	8.70	5.50	4.60	3.70	3.50	6.20	5.20
10	4.32	4.67	5.20	7.80	7.40	8.80	5.40	4.50	3.60	3.50	7.70	5.10
11	5.95	4.75	5.10	7.80	8.10	8.80	5.30	4.50	3.70	3.50	7.10	5.20
12	5.12	4.75	5.00	7.80	8.30	8.70	5.20	4.40	3.70	3.50	7.00	5.50
13	4.72	4.85	4.80	7.90	8.40	8.50	5.20	4.80	3.70	3.50	6.30	6.60
14	4.60	4.95	4.80	8.00	8.30	8.00	5.10	4.10	3.80	4.70	6.00	7.30
15	4.42	5.00	4.90	8.10	7.40	7.90	5.10	3.90	3.80	4.60	6.50	7.90
16	4.35	4.90	6.60	8.20	7.90	8.00	5.00	4.00	3.80	4.60	7.10	8.20
17	4.92	4.90	6.30	7.90	7.00	7.90	5.00	3.90	3.80	4.40	6.80	6.90
18	4.92	5.02	5.70	7.80	7.30	7.80	4.90	3.90	3.80	4.60	6.70	6.80
19	4.92	5.20	5.60	7.50	7.30	7.70	4.90	3.90	3.80	4.70	6.70	6.90
20	4.82	5.40	6.20	7.60	7.70	7.80	4.90	3.90	3.75	4.80	6.50	6.80
21	4.80	5.60	5.90	7.80	7.30	7.40	4.80	3.80	3.70	4.80	6.70	7.00
22	4.80	5.50	5.80	7.80	7.10	6.90	4.80	3.80	3.60	6.10	6.60	6.80
23	4.87	5.40	9.10	7.50	7.40	6.80	4.70	4.10	3.70	5.70	6.50	6.90
24	4.82	5.40	11.40	6.90	7.30	6.80	4.70	4.10	3.70	5.40	6.80	6.80
25	4.72	5.30	12.50	6.60	7.00	6.50	4.70	4.00	3.70	5.20	5.68	6.80
26	4.72	5.20	8.60	6.40	6.40	6.30	4.70	4.00	3.70	5.20	5.60	6.90
27	4.80	5.10	7.70	6.30	6.40	6.40	4.70	3.90	3.65	5.10	5.40	6.70
28	4.85	5.10	7.50	6.30	6.50	6.20	4.60	3.80	3.70	5.00	5.60	6.70
29	4.97	.....	7.10	6.20	6.90	6.10	4.60	3.80	3.70	5.00	5.70	6.90
30	4.92	.....	6.80	6.10	6.90	6.10	4.55	3.90	3.60	5.50	5.60	6.80
31	4.80	.....	6.60	.....	6.90	.....	4.50	3.80	.....	5.50	.....	6.40

SAN JOAQUIN RIVER AT HERNDON, CALIFORNIA.

The headwater tributaries of this river receive the drainage from the crests of the Sierras Nevada north of Mount Whitney. The fall of the river is rapid, with many favorable locations for power development, and in one case advantage has been taken of the fall on the North Fork and a power plant constructed developing electric power for transmission to Fresno and Hanford, California. During the last year a second storage reservoir has been under course of construction on the North Fork, which will tend further to regulate the flow of the river. No permanent diversions above the gaging station are made, but the water is extensively used below for irrigation purposes. The station was established by the Southern Pacific Railway Company in 1879. The old trestle bridge was torn down by the railroad company during the last year and a new iron structure was erected in its place. This necessitated a new gage rod, which was referred to the datum of the old gage and bolted to the western side of the central concrete pier. The bench mark is a nail in a post at the south end of the bridge on the west side, 0.2 foot above the ground and marked "B. M." It is at an elevation of 24.12 feet above gage datum. The channel for some distance above and below the bridge is straight and the water has a uniform velocity. The right bank is high, rocky, and steep. The bed of the stream is of sand and gravel. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 387; 1897, Nineteenth Annual Report,

Part IV, page 515; 1898, Twentieth Annual Report, Part IV, page 529. The following discharge measurements were made under the direction of J. B. Lippincott during 1899:

Discharge measurements of San Joaquin River at Herndon, California.

1899.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
March 5	3.25	786	June 27	4.90	2,922
April 18	6.34	5,310	August 1	3.32	743
May 18	7.00	7,435	September 8	2.67	196
June 2	5.76	4,177	September 8 *a*		269

a This measurement was made at Pollasky, California. The measurement made at the regular gaging station at 6 p. m. showed a loss by evaporation, etc., of 73 second-feet in 18 miles.

Daily gage height, in feet, of San Joaquin River at Herndon, California, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.67	3.17	3.25	4.71	4.29	5.63	5.08	3.33	2.67	2.33	2.75	3.00
2	2.67	3.17	3.25	4.58	4.38	5.63	4.96	3.25	2.67	2.33	2.70	3.00
3	2.67	3.17	3.25	4.42	4.25	5.42	5.00	3.25	2.67	2.33	2.63	3.00
4	2.75	3.08	3.25	4.42	4.25	5.38	4.96	3.25	2.67	2.33	2.67	3.00
5	2.67	3.00	3.25	4.62	4.29	5.71	4.92	3.25	2.67	2.33	2.67	3.00
6	2.67	3.00	3.25	4.67	4.38	6.54	4.63	3.00	2.67	2.33	2.67	3.00
7	2.67	3.00	3.25	5.75	4.50	7.13	4.54	3.00	2.67	2.33	2.58	2.75
8	2.67	3.00	3.25	5.67	4.50	7.17	4.42	3.00	2.67	2.25	2.58	2.75
9	2.92	2.92	3.42	6.33	4.71	7.50	4.25	3.08	2.67	2.25	2.58	2.75
10	3.00	2.92	3.42	6.29	5.25	7.75	4.21	3.08	2.67	2.25	2.50	2.75
11	3.25	3.00	3.42	6.04	6.21	7.67	4.17	3.17	2.67	2.25	3.50	2.75
12	3.67	3.00	3.33	6.17	6.96	7.58	4.17	3.17	2.58	2.25	3.25	2.67
13	3.25	3.00	3.25	6.21	6.96	7.42	4.17	3.08	2.50	2.83	3.88	3.00
14	3.00	3.00	3.25	6.38	6.71	7.13	3.96	3.08	2.50	2.42	3.67	2.87
15	3.00	3.00	3.25	6.58	6.13	7.00	3.92	3.00	2.50	2.42	3.50	3.20
16	3.00	3.08	3.25	7.08	5.67	6.96	3.88	2.92	2.50	2.58	3.29	6.00
17	3.08	3.17	3.62	6.70	5.63	6.92	3.83	2.92	2.50	2.58	3.63	5.12
18	3.08	3.17	3.50	6.29	5.58	6.79	3.83	2.83	2.50	2.58	3.50	4.16
19	3.08	3.17	3.33	6.33	5.58	6.71	3.75	2.83	2.42	2.66	3.29	4.10
20	3.08	3.50	3.37	6.21	5.46	6.79	3.75	2.83	2.42	2.66	3.17	3.91
21	3.08	3.54	3.62	6.25	5.25	6.50	3.75	2.83	2.42	2.66	3.17	3.88
22	3.00	3.58	3.67	6.17	5.54	6.00	3.75	2.83	2.42	2.75	3.17	3.67
23	3.17	3.58	4.58	6.25	6.00	5.88	3.75	2.83	2.42	3.33	3.33	3.54
24	3.08	3.58	9.21	5.91	6.08	5.67	3.58	2.83	2.33	3.33	3.21	3.33
25	3.08	3.58	10.40	5.38	5.92	5.88	3.50	2.83	2.33	3.00	3.17	3.33
26	3.00	3.42	8.75	5.04	5.58	5.67	3.67	2.83	2.33	3.00	3.25	3.25
27	3.00	3.33	7.17	5.00	5.25	5.13	3.75	2.83	2.33	2.96	3.08	3.25
28	3.17	3.25	5.75	4.92	5.17	4.83	3.54	2.83	2.33	2.86	3.08	3.25
29	3.17	.....	5.62	4.88	5.17	4.96	3.50	2.75	2.33	2.80	3.00	3.25
30	3.17	.....	5.37	4.54	5.79	5.00	3.50	2.75	2.33	2.80	3.00	3.25
31	3.17	.....	4.91	.....	5.38	.....	3.50	2.75	.....	2.75	.....	5.90

[Continued in Water-Supply and Irrigation Paper No. 39.]

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No. 39

OPERATIONS AT RIVER STATIONS, 1899.—PART V

WASHINGTON
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1900

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

OPERATIONS AT RIVER STATIONS, 1899

A REPORT OF THE

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UNITED STATES GEOLOGICAL SURVEY

PART V

WASHINGTON

GOVERNMENT PRINTING OFFICE

1900

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OPERATIONS AT RIVER STATIONS, 1899.

PART V.

MEASUREMENTS AT RIVER STATIONS.[1]

KINGS RIVER AT RED MOUNTAIN, CALIFORNIA.

This river rises on the western slope of the Sierra Nevada in Fresno County, California. The waters coming from the high catchment basin are probably of greater value for irrigation purposes than those of any other stream in central California, being used exclusively for the raising of grapes and deciduous fruits in the neighborhood of Fresno, Selma, and Hanford. The summer flow of this river is now entirely diverted, and during the dry season of the last few years the scarcity of water has worked many hardships. There is a large surplus of water in this river in the spring of the year, due to the melting of snows, which is now going to waste, and which, if stored in suitable reservoirs, would bring larger areas under cultivation. The mountainous basin of this river has never been systematically explored for reservoir sites. Two gaging stations were formerly maintained on the river; one at Red Mountain and the other at Kingsburg, California. The station at Red Mountain, established September 3, 1895, is located 15 miles east of Sanger, California, and southwest of Red Mountain. The station is on what is called "the lower section of No. 9" of the lumber flume. It is located at the mouth of the canyon, above all diversions. The bed of the stream is of gravel, and few changes have been noticed in the cross section since the establishment of the station. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 392; 1897, Nineteenth Annual Report, Part IV, page 519; 1898, Twentieth Annual Report, Part IV, page 535. The following discharge measurements were made under the direction of J. B. Lippincott during 1899:

Discharge measurements of Kings River at Red Mountain, California.

1899.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
April 19	8.8	5,409	August 2	4.66	608
May 15	8.15	4,422	September 4	3.8	206
June 3	7.85	3,954	December 8	4.36	458
June 26	7.23	3,049	December 21	5.3	a 974

a Measured at point 2 miles below gaging station.

[1] Continued from Water-Supply and Irrigation Paper No. 38.

Daily gage height, in feet, of Kings River at Red Mountain, California, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.80	4.60	4.90	6.40	6.90	8.50	7.30	4.70	3.80	3.60	4.20	4.50
2	3.80	4.70	4.90	6.40	6.80	8.40	7.30	4.70	3.80	3.60	4.20	4.40
3	4.00	4.60	4.90	6.50	6.80	8.40	7.30	4.60	3.80	3.60	4.10	4.40
4	4.20	4.40	4.90	6.60	6.80	8.00	7.10	4.50	3.90	3.60	4.20	4.40
5	3.90	4.40	4.90	7.60	6.00	8.70	6.50	4.40	3.90	3.60	4.20	4.50
6	3.90	4.40	5.00	7.80	7.00	10.00	6.80	4.40	3.80	3.60	4.10	4.40
7	4.00	4.30	5.00	8.00	7.10	10.10	6.50	4.50	3.80	3.60	4.10	4.30
8	4.20	4.40	5.10	8.40	7.80	10.00	6.30	4.50	3.70	3.60	4.05	4.30
9	4.10	4.40	5.20	8.60	7.70	10.20	6.20	4.40	3.80	3.60	4.80	4.40
10	4.20	4.50	5.10	8.60	7.80	10.30	6.10	4.40	3.70	3.60	5.50	4.20
11	5.80	4.50	5.10	8.70	7.90	10.40	6.00	4.40	3.70	3.65	4.80	4.30
12	5.00	4.50	4.90	8.70	7.70	10.50	5.90	4.30	3.70	3.70	5.40	4.40
13	4.70	4.50	4.80	8.70	7.80	10.00	5.80	4.30	3.80	3.85	5.10	4.40
14	4.60	4.60	4.80	9.00	7.90	9.40	5.70	4.20	3.70	3.95	4.90	4.60
15	4.50	4.60	4.70	9.30	7.70	9.60	5.60	4.20	3.70	4.00	4.70	5.40
16	4.60	4.60	4.90	9.50	7.80	9.50	5.60	4.20	3.70	4.50	5.70	8.60
17	4.60	4.70	4.90	8.90	7.90	9.50	5.50	4.20	3.70	4.10	5.20	6.40
18	4.60	4.70	5.00	9.10	8.00	9.40	5.40	4.10	3.70	4.20	5.00	5.80
19	4.60	4.80	5.00	8.60	8.20	9.10	5.50	4.20	3.60	4.25	4.80	5.60
20	4.50	5.10	5.40	9.00	7.70	9.00	5.40	4.10	3.70	4.25	4.60	5.40
21	4.50	5.40	5.50	9.20	8.30	8.50	5.30	4.10	3.60	4.30	4.70	5.30
22	4.50	5.40	6.40	9.30	8.20	8.30	5.30	4.00	3.60	5.65	5.00	5.20
23	4.60	5.30	7.80	9.00	8.30	8.10	5.20	4.10	3.60	5.40	4.80	5.20
24	4.50	5.30	9.70	8.30	8.40	8.10	5.10	4.00	3.60	4.70	4.70	5.20
25	4.50	5.30	13.80	8.30	8.00	7.70	5.30	4.00	3.60	4.50	4.70	5.20
26	4.50	5.10	8.20	7.70	7.90	7.50	5.30	3.90	3.60	4.45	4.70	5.20
27	4.50	4.90	7.70	7.50	7.90	7.10	5.20	3.90	3.60	4.45	4.70	5.20
28	4.60	4.90	7.10	7.70	8.40	7.30	5.10	3.90	3.60	4.40	4.60	5.10
29	4.60	.....	7.30	6.60	8.50	7.30	5.00	3.90	3.60	4.40	4.60	5.10
30	4.70	.....	6.80	7.10	8.40	7.30	4.90	3.90	3.60	4.35	4.50	7.10
31	4.60	.....	6.20	.....	7.90	.....	4.80	3.80	.....	4.30	.....	6.40

KINGS RIVER AT KINGSBURG, CALIFORNIA.

The Southern Pacific Railway Company has maintained gage readings at the railroad bridge 1 mile south of Kingsburg since 1879. Attempts have been made in previous years to establish a rating curve for this station, but it has been found impossible to do so on account of the fluctuations of the water surface caused by the manipulation of the head gates of the People's canal, 2 miles below, and also on account of the changes in the sandy bed of the river. The railroad company has maintained daily gage readings as given on the following page. No measurements of discharge were made at this point during 1899.

Daily gage height, in feet, of Kings River at Kingsburg, California, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.92	4.16	3.83	4.08	4.83	6.75	5.67	4.00	3.25	2.83	3.92	5.08
2	3.92	4.08	3.83	4.25	4.58	6.92	5.50	4.00	3.25	2.25	3.83	5.08
3	4.00	4.08	3.92	4.00	4.25	6.67	5.42	4.00	3.25	2.25	3.83	5.08
4	4.00	4.08	3.83	4.17	4.33	6.58	5.00	4.00	3.25	2.25	3.83	5.08
5	3.92	4.16	3.92	4.25	4.42	6.83	4.92	3.92	3.25	2.25	3.75	5.08
6	3.92	4.25	3.92	4.66	4.58	8.00	4.50	3.83	3.25	2.25	3.75	5.08
7	4.00	4.25	3.92	6.33	4.83	8.50	4.33	3.75	3.25	2.25	3.67	5.33
8	4.00	4.33	3.83	6.75	5.25	8.50	4.25	3.83	3.25	2.25	3.67	5.08
9	4.00	4.33	3.83	7.00	5.08	8.58	4.58	3.83	3.25	2.25	3.83	5.08
10	4.00	4.25	3.83	7.08	5.50	8.58	4.25	3.83	3.21	2.25	4.25	5.08
11	5.42	4.25	3.83	7.08	7.00	9.00	4.00	3.75	3.25	2.25	5.25	4.75
12	5.83	4.25	3.83	7.00	8.17	9.00	3.67	3.58	3.25	2.25	4.92	4.83
13	4.33	4.16	3.75	7.00	8.33	8.75	3.75	3.58	3.25	2.25	5.50	4.92
14	3.66	4.16	3.92	7.17	8.08	8.00	4.00	3.54	3.21	2.33	5.25	5.75
15	3.92	4.16	3.83	7.25	7.17	8.00	4.17	3.50	3.25	2.75	5.17	5.25
16	3.92	4.16	3.92	7.75	7.00	7.83	4.00	3.46	3.25	3.08	5.42	8.00
17	3.92	4.16	3.92	7.50	6.50	7.50	4.17	3.60	3.25	3.17	5.83	7.33
18	4.00	4.00	3.92	7.25	6.67	7.50	4.25	3.25	3.25	3.25	5.67	6.83
19	3.92	4.00	3.83	7.08	6.67	7.25	4.33	3.25	3.25	3.50	5.42	6.50
20	4.08	4.25	3.92	7.00	6.58	7.33	4.25	3.25	3.25	3.67	5.25	6.25
21	4.00	4.25	3.92	7.25	6.25	7.00	4.17	3.21	3.25	3.75	5.33	6.00
22	4.00	4.25	3.92	7.17	6.33	6.83	4.17	3.17	3.17	4.17	5.25	6.00
23	4.08	4.16	3.83	7.08	6.75	6.83	4.08	3.17	3.17	5.67	5.42	5.83
24	4.16	4.25	9.33	7.00	7.67	6.50	4.00	3.17	3.17	5.00	5.25	5.75
25	4.00	3.83	11.25	6.25	7.00	6.50	4.00	3.12	3.17	4.58	5.17	5.50
26	4.00	3.83	8.92	5.83	6.58	6.25	4.00	3.08	3.12	4.33	5.08	6.00
27	4.08	4.00	6.75	5.33	6.33	6.25	4.08	3.08	3.08	4.08	5.08	6.00
28	4.08	4.00	5.50	5.17	6.25	5.50	3.92	3.00	3.08	4.00	5.08	5.83
29	4.08	.....	5.33	4.92	6.42	5.58	4.00	3.00	3.08	4.00	5.17	6.00
30	4.16	.....	4.75	4.66	6.75	5.75	4.00	3.00	3.08	3.96	5.17	5.83
31	4.16	.....	4.42	.....	6.50	.....	4.00	3.25	.....	3.92	.....	7.50

KERN RIVER NEAR BAKERSFIELD, CALIFORNIA.

This river issues from the southern extremity of the Sierra Nevada, being formed by the junction of the North Fork and the South Fork a short distance below Kernville. The run-off from this basin is notably less than from the northern tributaries of San Joaquin River, which may be due to the fact that a portion of the basin is located east of the main crest of the mountains and is therefore protected from the water-bearing clouds. Most of the water of Kern River is used for irrigation by the large canals in the southern end of San Joaquin Valley. The winter waters are in part stored in Buena Vista Lake, which was a number of years ago converted into a storage reservoir. The station was established in 1893 by Mr. Walter James, chief engineer of the Kern County Land Company, and is located at what is known as "the first point of measurement," 5 miles above Bakersfield and at the mouth of the canyon of the river. Meter measurements are taken once a week, and an automatic gage records the fluctuations of the river heights. Mr. A. K. Warren, the engineer in charge of this work for the Kern County Land Company, attends to the measurements with much accuracy and precision, and furnishes this office with the final results. The results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 297; 1897, Nineteenth Annual Report, Part IV, page 523; 1898, Twentieth Annual Report, Part IV, page 536.

Daily discharge, in second-feet, of Kern River at "first point of measurement," California.

1896.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	379	766	740	1,100	1,009	3,067	1,299	713	384	241	397	330
2	377	732	713	1,044	994	3,200	1,244	671	365	240	384	319
3	382	695	724	1,015	1,011	2,875	1,221	642	339	241	384	335
4	404	660	690	974	1,074	2,628	1,237	607	328	246	364	350
5	393	639	685	942	1,126	2,592	1,434	590	289	247	349	357
6	379	640	707	916	1,205	2,741	1,879	542	279	250	338	365
7	378	624	695	889	1,146	2,854	1,929	514	312	251	333	370
8	394	593	695	861	1,115	3,069	1,698	496	428	236	328	351
9	400	580	705	870	1,086	3,348	1,570	475	454	228	316	325
10	403	591	726	932	1,015	3,379	1,822	451	399	232	321	320
11	397	598	726	925	978	3,118	1,874	450	360	239	347	335
12	390	598	732	911	952	2,939	1,792	442	329	243	406	330
13	385	599	755	970	986	3,028	1,624	440	306	243	385	332
14	387	591	777	1,045	1,082	2,960	1,447	412	294	241	380	337
15	397	590	822	1,151	1,175	2,801	1,272	381	285	238	380	336
16	397	583	827	1,050	1,173	2,715	1,116	366	269	239	365	369
17	469	576	833	933	1,140	2,686	1,056	379	257	238	351	370
18	519	593	864	864	1,175	2,786	1,144	478	244	250	349	342
19	918	590	867	852	1,205	2,553	1,096	588	247	247	341	332
20	915	582	880	850	1,204	2,300	1,027	644	251	254	345	330
21	3,101	577	924	842	1,184	2,138	963	602	268	268	349	342
22	2,327	572	1,068	832	1,229	1,985	986	536	275	262	354	353
23	1,390	577	1,133	861	1,222	1,884	1,219	481	276	258	356	339
24	1,067	571	1,209	864	1,247	1,680	2,004	442	273	265	355	342
25	888	587	1,232	920	1,362	1,553	1,686	425	282	268	374	241
26	844	596	1,375	1,171	1,568	1,442	1,380	412	282	265	387	342
27	844	618	1,782	1,245	1,971	1,333	1,179	401	280	302	351	347
28	1,125	661	1,648	1,201	2,489	1,301	1,029	386	268	364	326	362
29	906	724	1,453	1,088	2,998	1,346	903	378	248	403	299	378
30	867	.....	1,296	1,056	3,283	1,369	830	364	237	376	329	352
31	757	.....	1,211	.....	3,042	.....	765	310	.....	393	.....	355
Mean	747	617	951	972	1,401	2,456	1,346	486	304	267	355	347

1897.

1	386	1,458	777	1,251	4,163	4,045	1,347	631	341	288	391	382
2	355	2,065	846	1,238	4,185	3,638	1,387	606	345	297	377	393
3	319	1,310	787	1,141	4,187	3,428	1,442	606	344	310	357	388
4	314	963	782	1,130	4,536	3,312	1,439	607	347	312	348	342
5	338	822	714	1,274	4,857	3,308	1,311	600	347	303	345	332
6	357	1,292	694	1,516	4,948	3,352	1,260	576	342	290	338	348
7	351	1,169	857	1,816	4,845	3,387	1,175	536	330	293	340	352
8	352	978	849	2,025	4,658	3,260	1,072	507	309	297	346	368
9	361	791	789	2,141	4,504	3,087	1,002	525	297	297	345	733
10	365	660	818	2,354	4,425	3,062	958	511	288	303	322	680
11	367	632	837	2,580	4,505	2,890	957	493	287	309	329	564
12	357	606	827	2,811	4,567	2,600	1,010	457	294	303	339	509
13	360	605	789	3,116	4,577	2,540	1,055	438	295	299	340	474
14	363	562	763	3,376	4,610	2,527	1,142	424	297	315	336	476
15	369	534	756	3,564	4,531	2,413	1,156	412	295	330	330	483
16	370	532	741	3,822	4,482	1,189	1,151	417	290	392	321	446
17	357	544	780	3,953	4,355	1,853	1,108	423	285	377	303	405
18	337	609	780	4,216	4,252	1,617	1,045	448	278	368	302	397
19	327	678	855	4,217	4,338	1,492	988	438	272	360	306	401
20	318	619	936	3,973	4,470	1,423	947	424	268	353	312	406
21	324	635	906	3,681	4,617	1,374	868	440	269	341	317	358
22	336	626	843	3,526	4,815	1,351	868	467	273	334	328	344
23	343	573	831	3,412	5,066	1,393	840	459	280	346	417	358
24	353	573	850	3,212	5,227	1,403	782	423	286	366	415	387
25	363	617	921	3,140	5,083	1,433	740	393	288	394	436	403
26	372	684	1,079	3,368	4,802	1,431	710	386	286	382	441	408
27	369	749	1,256	3,585	4,614	1,386	688	391	279	372	402	399
28	392	771	1,298	3,865	4,548	1,368	679	396	281	387	403	387
29	452	.....	1,891	4,060	4,479	1,356	681	388	271	386	392	386
30	575	.....	1,471	4,056	4,407	1,349	674	368	274	386	383	384
31	667	.....	1,291	.....	4,340	.....	658	350	.....	390	.....	376
Mean	373	809	923	2,914	4,580	2,309	1,006	469	298	340	355	422

Daily discharge, in second-feet, of Kern River at "first point of measurement," California—Continued.

1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	381	332	435	390	877	608	399	132	115	220	136	195
2	379	346	414	385	790	645	365	134	117	208	141	198
3	392	357	430	400	711	662	330	125	111	191	152	196
4	388	356	436	401	678	597	308	127	108	190	158	192
5	384	344	422	381	670	563	303	131	108	181	166	192
6	388	355	402	414	632	597	304	133	107	177	173	191
7	381	639	418	474	580	634	825	136	108	173	181	192
8	381	704	427	465	613	641	341	139	105	165	175	191
9	391	569	434	451	659	635	319	131	102	156	163	184
10	368	483	458	488	712	613	288	125	101	156	161	179
11	354	469	479	552	839	575	284	122	100	157	158	174
12	356	454	448	593	921	543	262	124	97	152	158	160
13	355	433	406	601	904	508	257	120	94	155	158	154
14	379	436	388	632	928	513	252	126	89	156	158	163
15	376	434	373	667	874	554	275	126	85	154	152	176
16	386	426	373	698	889	556	267	128	91	156	149	189
17	373	429	381	718	837	593	248	125	93	157	154	192
18	359	434	374	755	807	621	238	120	95	157	159	189
19	348	430	364	804	781	599	229	117	99	156	167	197
20	356	418	333	879	723	592	205	117	100	152	173	198
21	365	415	335	944	657	554	197	120	98	148	184	209
22	347	407	348	816	611	532	189	117	97	147	182	264
23	340	396	332	777	620	520	188	111	100	147	177	268
24	357	377	323	821	638	519	184	110	99	148	188	280
25	342	392	338	996	635	488	162	107	102	149	186	213
26	347	455	356	1,108	613	411	155	104	116	151	178	214
27	350	428	348	1,233	720	423	157	93	135	151	171	217
28	337	436	341	1,237	818	420	151	97	175	145	167	214
29	342	.....	362	1,227	771	421	136	104	280	140	173	213
30	333	.....	379	995	675	405	131	110	243	133	184	212
31	325	.....	383	.....	612	.....	131	115	.....	132	.....	206
Mean	363	434	388	710	735	561	244	120	116	160	166	199

1899.

1	196	289	303	678	759	929	859	235	100	92	186	220
2	195	300	305	621	712	1,009	856	229	101	93	189	216
3	224	307	314	612	652	944	857	208	101	90	185	209
4	240	288	320	604	633	964	811	207	103	94	185	204
5	214	279	306	624	649	1,007	776	196	105	95	190	211
6	212	275	304	700	659	1,066	763	191	108	95	100	212
7	208	274	309	768	682	1,361	719	196	115	97	196	219
8	213	264	308	855	680	1,560	679	190	115	96	191	216
9	229	264	313	925	623	1,631	622	186	108	109	190	209
10	253	274	311	1,014	588	1,770	563	184	103	111	188	214
11	308	276	299	988	649	1,926	516	173	101	114	204	203
12	346	278	272	926	850	2,072	499	170	98	126	220	196
13	300	277	267	953	1,102	1,994	280	163	105	152	213	218
14	284	281	258	968	1,258	1,756	468	156	110	180	212	220
15	277	293	253	1,010	1,225	1,568	450	150	110	191	330	224
16	281	299	261	1,049	1,051	1,550	439	147	113	194	211	267
17	285	301	262	1,132	959	1,570	446	147	113	189	236	681
18	292	300	268	1,098	913	1,550	389	142	115	193	240	514
19	296	306	264	1,070	890	1,561	360	135	109	209	233	390
20	286	325	283	1,042	852	1,514	363	135	106	219	230	324
21	278	340	319	1,037	809	1,367	349	132	103	220	239	296
22	269	359	323	1,091	794	1,218	338	130	100	222	270	302
23	276	361	323	1,114	806	1,160	312	131	96	223	278	303
24	281	359	398	1,104	907	1,149	295	132	97	226	261	316
25	282	340	2,927	972	970	1,135	289	123	100	212	238	300
26	275	324	3,115	884	923	1,062	292	119	104	198	236	303
27	266	310	1,605	771	863	948	309	114	110	187	228	293
28	269	310	1,105	951	819	848	290	108	109	183	223	280
29	274	.....	877	709	822	846	266	106	98	183	222	289
30	274	.....	797	718	885	863	255	106	93	188	222	284
31	280	.....	722	.....	803	.....	239	102	.....	189	.....	318
Mean	263	302	590	893	835	1,331	489	156	105	160	221	278

MOHAVE RIVER AT VICTOR, CALIFORNIA.

The headwaters of this river have their source on the northern slope of the Sierra Madre and flow northerly, finally disappearing in the sands of the Mohave Desert. At Victor, a station on the Atchison, Topeka and Santa Fe Railroad, the river passes through a narrow gorge, locally known as The Narrows. This place has been under investigation as a possible dam site, and soundings for the depth of bed rock were made by the United States Geological Survey during the season of 1899. The greatest depth of bed rock was found to be 54 feet. The diamond drill showed the rock to be a fine granite. A more detailed account of this exploration will be given in the Twenty-first Annual Report, Part IV. Above The Narrows the valley broadens into a large reservoir site, but as no surveys of it have been made the capacity is unknown. In order to determine the amount of water available for storage for this reservoir, a gaging station was established February 27, 1899. The rod is a 2 by 6 inch timber, bolted to a vertical cliff on right bank of the river, 600 feet upstream from wagon bridge. The bench mark is top of east rail of the Santa Fe track, 75 feet south of center of wagon bridge over track. The zero mark of rod is 12.84 feet below bench mark. The following measurements of discharge were made under the direction of J. B. Lippincott during 1899:

February 27, gage height, 1 foot; discharge, 44 second-feet.
May 5, gage height, 0.90 foot; discharge, 32 second-feet.
June 13, gage height, 0.90 foot; discharge, 25 second-feet.
July 26, gage height, 0.85 foot; discharge, 22 second-feet.

Rating table for Mohave River at Victor, California, 1899.

Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*
0.80	17	1.00	44
0.85	22	1.10	60
0.90	28		

Daily gage height, in feet, of Mohave River at Victor, California, for 1899.

Day.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	1.00	1.10	1.00	1.00	0.90	0.90	0.85	0.85	0.90	0.90
2	.....	1.00	1.10	1.00	.90	.90	.85	.85	.85	.90	.90
3	.....	1.00	1.00	.90	1.00	.90	.85	.85	.85	.90	.90
4	.....	1.00	1.00	.90	.90	.90	.85	.85	.85	.90	.90
5	.....	1.00	1.00	.90	.90	.90	.85	.85	.85	.90	.90
6	.....	1.00	.90	.90	.90	.90	.85	.85	.85	.90	.90
7	.....	.90	1.00	1.00	.90	.90	.85	.85	.85	.85	.90
8	.....	.90	1.00	1.00	.90	.90	.85	.85	.85	.85	.90
9	.....	1.00	.90	1.00	.90	.90	.90	.85	.85	.85	.90
10	.....	1.00	1.00	.90	.90	.90	.90	.85	.85	.85	.90
11	.....	1.00	1.00	.90	.90	.90	.90	.85	.90	.85	.90
12	.....	1.00	1.00	.90	.90	.90	.90	.85	.80	.85	.90
13	.....	.90	.90	1.00	.90	.90	.85	.85	.85	.90	.90
14	.....	.90	1.00	1.00	.90	.90	.85	.85	.85	1.00	.....
15	.....	.90	1.00	1.00	.90	.90	.85	.85	.85	.90	.....
16	.....	1.00	.90	1.00	.90	.90	.85	.85	.85	.90	.....
17	.....	1.00	.90	.90	.90	.90	.90	.85	.85	.90	.....
18	.....	1.10	1.00	1.00	.90	.90	.90	.85	.85	.90	.....
19	.....	.90	1.00	1.00	.90	.90	.80	.85	.85	.90	.....
20	.....	.90	1.00	1.00	.90	.90	.85	.85	.85	.90	.....
21	.....	1.10	1.00	1.00	.90	.90	.85	.85	.85	.90	.....
22	.....	1.00	.90	1.00	.90	.90	.85	.85	.85	.90	.....
23	.....	1.00	1.00	1.00	.90	.90	.85	.85	.85	.90	.....
24	.....	1.00	1.00	1.00	.90	.90	.85	.85	.85	.90	.....
25	.....	1.00	1.00	1.00	.90	.90	.85	.85	.85	.90	.....
26	.....	1.00	1.00	.90	.90	.85	.90	.85	.85	.90	.....
27	1.00	.90	.90	.90	.90	.85	.90	.85	.90	.90	.....
28	1.00	1.00	1.00	.90	.90	.85	.85	.85	.90	.90	.....
29	.....	1.00	1.00	1.00	.90	.85	.85	.85	.90	.90	.....
30	.....	.90	1.00	1.00	.90	.85	.85	.85	.90	.90	.....
31	.....	1.00	.....	1.00	.....	.85	.85	.....	.90	.....	.....

No record December 14 to 31.

LOS ANGELES RIVER AT THE NARROWS, CALIFORNIA.

This river heads immediately south of Santa Clara River, its various tributaries receiving their water supply from the mountains surrounding the San Fernando plains. The river passes out of the lower end of the valley through a short gorge known as The Narrows, at the lower end of which is located the city of Los Angeles. The streams entering San Fernando Valley have in the past brought down immense quantities of sand and gravel from the mountainous area, and have thus formed the San Fernando plains. This coarse deposit acts as a natural reservoir, absorbing the floods, the water gradually appearing lower down. The rainfall of southern California has been deficient for the last few years, but the discharge of Los Angeles River at The Narrows has been exceptionally constant; in 1899 the decrease in discharge being not more than 10 per cent of the average. A study of the river has been made by J. B. Lippincott for the city of Los Angeles. The flow is of marked constancy, and it is believed that the measurements indicate with fair accuracy the discharge for the respective months. As in previous reports, the discharge measurements for 1899 include the flow of the river at bridge No. 2, the main supply ditch at a point opposite, and the Glassell tributary. In addition water is diverted for irrigation purposes from a point known as Formans Lake to the vicinity of Burbank; and also from the development works of the West Los

Angeles Water Company, to the south side of Cahuenga Mountains. Results of measurements for 1896 and to April, 1899, inclusive, may be found in the Twentieth Annual Report, Part IV, page 542. The following measurements of discharge were made by J. B. Lippincott during 1899:

Discharge measurements of Los Angeles River at The Narrows, California.

1899.

Date.	Discharge.	Date.	Discharge.
	Second-feet.		*Second-feet.*
January 5	67	August 25	59
February 14	61	September 20	53
February 25	67	September 27	54
March 11	63	October 25	57
March 25	61	October 31	56
April 29	52	November 17	59
May 18	58	November 28	56
June 7	56	December 13	58
July 18	55	December 26	58
August 19	57		

ARROYO SECO, CALIFORNIA.

This is a small basin draining 21 square miles of the Sierra Madre. The river issues from the mountains on the west side of Pasadena Mesa, passes through an opening in a granite spur known as Devils Gate, and joins Los Angeles River at Los Angeles. Between the point where the water issues from the mountain and Devils Gate lies a broad river bottom 2 miles in length and composed of coarse material. In passing over this the water sinks rapidly, diminishing in volume from the mouth of the canyon to Devils Gate. The following measurements were made at the cable station at the terminal quarries by E. P. Dewey and W. B. Clapp in 1899:

Discharge measurements made on Arroyo Seco, California.

1899.

Date.	Discharge.	Date.	Discharge.
	Second-feet.		*Second-feet.*
January 10	3.02	March 20	2.52
January 11	1.90	March 21	1.90
January 12	2.00	March 22	1.64
January 12	2.06	March 23	1.56
February 1	.24	March 26	2.20
March 17	3.24	March 28	1.22
March 18	1.77	April 2	.28
March 19	.93	April 12	.07

SAN GABRIEL RIVER ABOVE AZUSA, CALIFORNIA.

The drainage basin of this river lies on the southern slope of the Sierra Madre, the watershed being included in Los Angeles County, California. The various tributaries join the river before it enters its lowest canyon, whence it appears finally on the plain in the vicinity of

Azusa. The seepage waters of this valley appear lower down in the river and finally enter the Pacific Ocean not far from the mouth of Los Angeles River. All of the surplus waters of this stream are now used for irrigation purposes. Owing to the numerous diversions, it has been difficult to obtain accurate discharge measurements; but during 1898 the San Gabriel Electric Company completed its system, and measurements are now obtained with greater ease and hence with greater accuracy. The headworks of this company are located about 6 miles above the mouth of the canyon; the water is carried along the left side by a series of tunnels and conduits, and a head of 400 feet is obtained where the electric power is generated. Weirs are placed on the conduit of the electric company, and the water is measured at this point. The capacity of the conduit is 90 second-feet. The season of 1899 was notable in southern California for the deficiency of rainfall, and on six days only was there a surplus of water flowing past the gaging station. The following are the dates, with their respective discharges, on which water passed the gaging station in 1899:

January 11, gage height, 1.18 feet; discharge, 16 second-feet.
January 12, gage height, 1.08 feet; discharge, 12 second-feet.
January 13, gage height, 0.90 foot; discharge, 6 second-feet.
January 14, gage height, 0.78 foot; discharge, 2 second-feet.
January 15, gage height, 0.70 foot; discharge, 1 second-foot.
October 14, gage height, 1.10 feet; discharge, 13 second-feet.

From these measurements the following rating table was constructed:

Rating table for San Gabriel River above Azusa, California, 1899.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.40	0.0	1.00	9	1.60	38
0.50	0.2	1.10	13	1.70	45
0.60	0.5	1.20	17	1.80	53
0.70	1.2	1.30	21	1.90	63
0.80	3.0	1.40	26	2.00	80
0.90	6.0	1.50	31	.....	.....

During the rest of the year the entire flow passed through the electric company's canal. The gaging station on the main river is located at the mouth of the canyon. The equipment consists of a rod, cable, car, and tagged wire. Results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 405; 1897, Nineteenth Annual Report, Part IV, page 528; 1898, Twentieth Annual Report, Part IV, page 550. The first of the following tables shows the dates in 1898 at which there was water in the main river, together with the amount of discharge. The next table shows the combined discharge for 1898 of the canals diverting water at the mouth of the canyon. A part of this table, from September to December, inclusive, was published in Water-Supply Paper No. 28, page 190; but the data for

the previous portion of the year having now been obtained, the entire table is here given. Dates in 1899 on which there was water passing the gaging station on the main river are given above. Following the table of canal discharges for 1898 is a table showing the daily discharge of San Gabriel canals for 1899. The total flow of the river is obtained by adding the daily discharge for the river to the figures, for the corresponding dates, for the canals.

Daily discharge, in second-feet, of San Gabriel River above Azusa, California, for 1898.

Day.	Jan.	Feb.	Mar.	Apr.	May.	Day.	Jan.	Feb.	Mar.	Apr.	May.
1	0.0	8.0	0.0	0.0	0.0	17	19.0	31.0	0.0	0.0	11.0
2	0.0	9.0	0.0	0.0	0.0	18	17.0	11.0	0.0	0.0	9.0
3	0.0	9.0	0.0	0.0	0.0	19	17.0	11.0	0.0	0.0	9.0
4	0.0	9.0	0.0	0.0	0.0	20	17.0	11.0	0.0	0.0	9.0
5	0.0	0.2	0.0	0.0	18.0	21	17.0	11.0	0.0	0.0	0.0
6	0.0	0.2	0.0	0.0	0.0	22	17.0	11.0	0.0	0.0	0.0
7	0.0	0.2	0.0	0.0	0.0	23	15.0	9.0	0.0	0.0	0.0
8	0.0	41.0	0.0	0.0	0.0	24	15.0	0.0	0.0	0.0	0.0
9	26.0	31.0	0.0	0.0	0.0	25	15.0	0.0	0.0	0.0	0.0
10	31.0	26.0	1.0	0.0	0.0	26	15.0	0.0	0.0	0.0	0.0
11	26.0	21.0	0.0	0.0	0.0	27	15.0	0.0	0.0	0.0	0.0
12	24.0	15.0	0.0	0.0	0.0	28	15.0	0.0	0.0	0.0	0.0
13	24.0	13.0	0.0	0.0	0.0	29	15.0	.....	0.0	0.0	0.0
14	24.0	11.0	0.0	0.0	0.0	30	15.0	.....	0.0	0.0	0.0
15	21.0	9.0	0.0	0.0	63.0	31	9.0	.....	0.0	.....	0.0
16	21.0	31.0	0.0	0.0	24.0						

River dry June 1 to December 31.

Daily discharge, in second-feet, of the San Gabriel canals above Azusa, California, for 1898.

[Drainage area, 222 square miles.]

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	28.0	28.0	33.0	36.5	26.0	30.0	14.5	9.5	8.2	9.0	9.0	11.7
2	28.0	28.0	32.0	37.0	39.0	28.0	13.0	9.5	10.0	9.8	8.5	11.8
3	28.0	28.0	31.0	37.0	37.0	25.0	13.5	9.5	8.2	10.0	8.5	11.8
4	28.0	28.0	31.0	37.0	36.0	23.5	13.0	9.0	8.2	10.5	8.0	11.9
5	27.0	32.0	31.0	37.5	34.0	22.8	13.0	9.0	8.2	9.0	8.5	11.9
6	27.0	32.0	31.0	36.5	31.5	21.0	12.0	9.0	8.2	9.0	9.0	11.9
7	27.0	32.0	30.0	36.0	32.0	20.2	14.0	8.5	7.9	8.5	9.0	12.0
8	27.0	29.0	30.0	35.0	31.0	20.0	12.5	8.5	7.9	8.5	9.0	12.0
9	32.0	29.0	28.0	35.0	30.0	20.0	11.5	8.5	8.0	8.5	8.5	12.0
10	32.0	29.0	34.0	35.0	28.0	21.5	11.5	8.4	8.0	9.0	8.7	12.2
11	31.0	29.0	34.0	34.0	25.0	23.5	11.0	8.5	7.5	8.7	9.0	12.5
12	25.0	32.0	32.5	32.5	25.0	22.0	11.0	8.5	7.5	8.0	9.8	12.6
13	25.0	32.0	34.0	32.5	25.0	21.4	10.0	8.4	7.5	8.0	9.8	12.6
14	25.0	32.0	33.5	32.5	25.5	21.0	10.0	6.5	7.5	7.5	9.2	12.6
15	25.0	32.0	33.5	34.0	20.0	20.2	9.7	7.0	7.0	7.5	9.8	18.2
16	25.0	10.0	36.0	34.0	27.5	18.0	10.0	7.0	7.0	7.5	9.8	15.2
17	25.0	10.0	36.0	34.0	45.5	17.5	9.7	7.0	6.7	8.0	9.8	15.0
18	25.0	29.0	37.0	34.0	40.0	16.2	10.0	7.0	6.5	8.0	9.0	15.0
19	25.0	29.0	37.0	33.0	38.5	15.2	10.0	5.0	6.5	8.4	10.1	14.4
20	25.0	29.0	37.0	33.0	33.5	17.0	10.0	5.5	6.1	8.6	10.5	14.5
21	25.0	29.0	37.0	32.0	37.0	16.0	11.5	6.0	7.5	7.9	10.5	14.5
22	24.0	29.0	36.0	30.0	36.0	17.0	11.5	6.0	7.5	8.2	10.5	14.5
23	24.0	29.0	34.0	29.0	35.0	17.3	11.5	6.0	7.5	9.0	11.2	14.5
24	23.0	34.0	34.0	27.0	32.5	17.0	9.5	6.0	7.5	10.0	11.2	14.5
25	23.0	34.0	34.0	26.0	30.5	16.0	9.5	5.5	8.5	9.0	10.5	14.8
26	23.0	34.0	48.0	25.3	30.0	16.0	9.0	5.5	8.5	9.1	10.5	14.0
27	23.0	34.0	41.0	25.3	30.0	16.0	9.0	6.3	7.5	9.1	10.5	14.0
28	23.0	34.0	39.0	27.0	30.5	15.8	9.0	7.5	10.2	8.9	11.0	14.0
29	23.0	.....	36.0	30.0	29.5	15.0	9.5	7.0	8.0	8.9	11.5	14.3
30	23.0	.....	36.0	35.5	30.5	14.5	9.5	7.0	10.2	8.4	11.5	14.0
31	28.0	.....	37.0	.....	30.0	.....	9.5	7.0	.....	8.4	.....	14.5
Mean	25.9	29.1	34.6	32.8	31.7	19.5	10.9	7.4	7.9	8.7	9.8	13.5

Daily discharge, in second-feet, of the San Gabriel canals above Azusa, California, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	14.8	27.2	20.3	28.0	17.5	22.2	4.0	5.0	3.4	3.7	12.0	16.2
2	24.2	28.0	20.3	27.5	17.5	20.0	4.0	5.1	3.0	4.0	11.5	16.0
3	20.3	26.2	21.5	25.2	17.0	17.0	4.0	5.5	4.0	4.0	11.5	16.0
4	19.0	24.2	19.4	24.8	17.0	15.0	4.0	5.5	4.3	4.0	11.7	16.0
5	19.0	23.5	18.7	24.8	15.5	14.8	4.0	6.0	3.7	4.0	10.1	16.3
6	18.0	23.5	18.5	25.0	17.5	13.5	4.2	6.0	4.3	4.0	10.2	16.0
7	18.0	23.5	18.0	24.0	17.5	12.0	4.2	5.0	3.7	4.3	10.2	16.0
8	18.0	23.5	18.5	22.2	16.5	11.0	3.5	4.7	4.5	3.7	10.2	15.7
9	18.0	23.4	18.7	22.0	15.5	9.7	3.4	4.7	5.5	3.7	10.3	15.5
10	22.0	23.4	18.7	23.5	14.0	8.5	3.4	4.5	5.0	4.4	12.0	15.5
11	33.0	23.4	19.0	23.5	13.0	8.8	3.5	4.7	4.0	8.5	12.0	15.5
12	32.0	23.4	19.0	22.2	13.0	9.0	3.4	4.5	4.0	9.0	12.0	15.5
13	22.0	23.0	19.0	21.0	12.5	9.5	3.0	4.5	3.6	22.0	12.0	15.5
14	22.0	21.8	19.0	21.0	12.0	9.2	3.4	4.3	3.8	22.0	14.5	15.5
15	22.0	21.6	19.0	20.5	12.5	8.0	3.5	4.0	4.2	26.0	15.0	16.0
16	22.0	20.3	31.2	20.0	14.1	7.8	3.5	4.0	4.0	19.0	15.0	23.0
17	18.0	20.0	36.4	19.7	13.0	7.5	3.3	4.5	3.7	16.0	15.0	39.0
18	18.0	20.0	35.0	19.5	13.0	7.5	3.0	6.0	3.7	15.0	14.0	30.0
19	19.7	19.7	29.0	19.5	13.5	7.3	3.0	6.0	3.7	13.5	14.0	28.0
20	19.3	19.7	39.5	18.5	11.5	7.0	3.0	6.0	3.7	13.5	14.0	25.0
21	20.4	19.7	37.4	17.0	11.5	7.0	3.0	5.5	3.3	13.0	16.0	23.0
22	21.6	19.7	32.7	16.5	11.5	6.2	3.3	5.5	3.3	13.5	23.5	22.5
23	22.8	20.3	31.7	16.2	11.5	6.2	3.5	5.0	3.3	14.0	20.0	21.5
24	23.6	22.4	32.5	17.5	12.0	6.2	3.5	4.0	3.0	14.0	18.3	20.7
25	24.0	21.8	35.5	19.3	12.0	6.2	3.5	4.0	3.0	12.5	18.0	20.7
26	24.0	21.2	35.4	21.0	12.0	6.2	4.0	4.0	3.0	12.0	17.2	20.7
27	24.1	21.2	32.0	21.3	11.5	6.0	4.0	4.0	3.3	12.0	17.0	20.7
28	23.5	21.0	32.0	20.5	11.5	5.5	4.0	5.5	3.3	12.3	17.0	21.0
29	23.2	.....	31.6	18.0	12.7	5.5	4.0	4.0	3.3	11.5	16.7	23.0
30	24.2	.....	30.0	17.5	12.0	4.9	4.0	4.0	3.7	13.0	16.3	23.0
31	26.2	.....	29.5	.....	13.5	.....	4.0	4.0	.....	12.3	.....	22.0
Mean	21.8	22.4	26.4	21.2	13.7	9.5	3.6	4.8	3.7	11.1	14.2	20.3

LYTLE CREEK AT MOUTH OF CANYON, CALIFORNIA.

This small stream drains the southern slope of the Sierra Madre and discharges its waters onto the plains northwest of San Bernardino. Although it drains a comparatively small area of 54 square miles, at the mouth of the canyon its waters are important for irrigation purposes. Owing to the controversies which have arisen over its diversions, a number of lawsuits for the settlement of the claims have been instituted from time to time. A number of measurements of this stream at the mouth of the canyon from 1892 to 1896, inclusive, are given below. They are copied from court records of proceedings in which the water supply of this creek was involved. These cases were tried in the San Bernardino courts by Judge A. W. McKinley. The measurements were made by A. H. Koebig and G. O. Newman, on weirs, and are believed to be accurate.

Discharge measurements of Lytle Creek at mouth of canyon, California.

Date.	Discharge.	Date.	Discharge.
1892.	*Second-feet.*	1894.	*Second-feet.*
June 8	35.58	August 19	11.44
September 20	18.70	August 25	12.32
September 30	22.04	October 3	16.20
October 28	20.64	1895.	
November 21	22.04	September 2	56.10
November 27	20.68	September 30	40.78
1893.		1896.	
September 7	49.20	March 3	18.08
September 18	49.20	April 23	19.14
September 25	46.34	April 24	18.60
October 4	45.30	April 25	20.52
1894.		May 3	18.52
June 6	17.96	May 4	17.26
June 8	15.50	May 10	18.16
July 10	13.22	May 25	15.32
July 11	13.22	May 26	12.84
July 25	13.86		

Beginning in 1894, measurements of Lytle Creek were also made by H. D. Sibley, who was zanjero of the Lytle Creek canals at that time. The measurements were usually made because the discharge of the stream was below normal. In the winter and spring only the amount of water needed for irrigation was turned into the ditches, but later in the summer the entire flow was diverted. These measurements also were made over weirs, and are believed to be fairly accurate. During 1898 trouble was experienced by miners taking the water from the natural channel and turning it into dry channels, sluice boxes, weirs, mill races, etc., thereby causing a loss of from 20 to 25 per cent of the total flow of the creek. Only a portion of these latter diversions were returned to the creek. The measurements of Mr. Sibley would not show the full flow of Lytle Creek at all times, and sometimes show less than the full discharge, for the reasons mentioned above. During 1899 the amount of water which was diverted into the main canal was measured daily by the Anglo-American Canaigre Company, at a weir erected near the head of its cement ditch. The volumes given have been occasionally checked by visiting the canal and making meter measurements. It is believed that during 1899 practically all of the water of the stream was diverted into the canal.

Discharge, in second-feet, of Lytle Creek main canal above Rialto, California.

1894.

[Drainage area, 54 square miles.]

Day.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1			15.5					
2								
3		24.1	17.2		10.9		13.5	
4								
5	16.1			10.8				
6		22.6						
7			14.1				11.4	14.5
8	19.9				10.8	13.0		
9								13.7
10								
11	17.8	18.5	14.3	10.8			13.7	
12								
13	21.8			13.4				
14			14.3			13.2		
15								
16	22.6		14.4					
17		19.1						
18			15.0		13.7	11.5	14.5	
19	22.6			14.1				
20								
21			14.8	12.7				
22	24.9				11.9	12.7		12.9
23			14.6					
24		18.2	14.9					
25	25.4						14.2	
26								
27			15.0					
28		16.6						
29								
30								12.5
31				11.7	13.4			

1895.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1			54.4						
2									
3							36.9		
4			68.0			51.4			
5									
6									
7								80.5	
8		33.9					31.5		
9									
10						48.8			
11								24.9	
12						50.8			
13									22.0
14									
15									
16					50.4				
17						44.8			
18	26.4	43.8					41.9		
19									
20									
21		57.5					36.5		
22							34.1	24.0	
23	37.4				52.5				
24						47.1			
25									
26					54.4				
27									
28						36.5	34.5		
29									
30									
31							34.5		

June 5 to August 16 ditch broken, no measurements.

Discharge, in second-feet, of Lytle Creek main canal above Rialto, California—Continued.

1896.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1					17.8				13.2			
2				22.2		14.1	11.1					
3												
4												
5	20.0									12.2		
6						11.4			12.2			
7								11.5				
8		19.2					11.1					
9						13.5				11.6		16.0
10						12.5			12.2			
11												
12						11.9		10.5				
13		18.4										
14						12.2	12.2					16.0
15				24.9								
16	21.4				17.1			13.7	10.8			17.0
17			19.8									
18				19.7				11.3				
19									11.8			
20							10.5					
21								12.0				
22												16.0
23								12.5		11.1		
24				22.4				12.5				
25											28.0	
26									11.8	20.0		
27							10.7					
28								13.5				
29		17.5										
30					15.0							24.0
31												

Heavy rains March 1 to 5 and October 26; all water turned out of canal.

1897.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.
1								
2								
3		60.0						
4					36.0			
5								
6			60.0					
7		24.0						
8								
9				50.0	30.0			
10	16.0							
11								
12								10.6
13								
14			60.0					
15								
16	24.0				34.0			
17								
18		80.0						
19				60.0				
20								
21		50.0						
22								
23								
24				50.0				
25	20.0		60.0					
26								
27								
28		56.0	70.0	40.0				
29	28.0							
30								
31								

Heavy rains February 3 and 18, March 28, September 14. Chicala Water Company took charge of station June 1.

Discharge, in second-feet, of Lytle Creek main canal above Rialto, California—Continued.

1898.

Day.	May.	June.	July.	Day.	May.	June.	July.	Day.	May.	June.	July.
1	.....	.....	10.9	12	.....	.....	.....	22	.....	11.7	.....
2	.....	.....	.....	13	.....	.....	.....	23	.....	.....	.....
3	.....	.....	.....	41	.....	.....	.....	24	.....	.....	.....
4	.....	.....	.....	15	.....	13.9	.....	25	.....	.....	.....
5	.....	.....	.....	16	.....	.....	.....	26	.....	.....	.....
6	.....	.....	.....	17	.....	.....	.....	27	.....	.....	.....
7	.....	.....	.....	18	.....	.....	.....	28	14.6	09.0	.....
8	.....	.....	.....	19	.....	.....	.....	29	.....	.....	.....
9	.....	.....	.....	20	.....	11.5	.....	30	.....	.....	.....
10	.....	.....	.....	21	.....	.....	.....	31	.....	.....	.....
11	.....	.....	.....								

No measurements for January to April, inclusive, and August to December, inclusive.

1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	11.1	11.8	11.2	9.7	11.2	12.2	6.3	9.4	14.5	10.9	10.5	11.1
2	11.1	12.1	11.1	8.9	10.9	10.4	6.8	10.4	15.1	10.8	10.3	11.3
3	12.1	12.1	11.2	8.5	10.9	9.7	6.4	9.6	16.6	10.8	10.3	11.4
4	11.4	12.4	11.1	12.6	10.5	9.5	6.4	10.7	16.7	10.8	10.6	11.1
5	11.7	12.4	10.8	12.5	10.5	9.4	6.4	12.2	16.0	10.7	10.5	11.3
6	11.6	12.5	10.6	12.1	10.5	9.6	6.4	11.0	16.0	10.6	10.6	11.3
7	11.6	12.6	10.4	11.9	10.5	9.2	6.3	10.8	16.0	10.1	10.6	11.3
8	11.6	12.4	10.4	11.8	10.2	9.0	6.2	11.0	15.9	9.9	9.9	11.6
9	11.6	12.1	10.9	11.7	11.8	.....	6.2	11.0	16.5	10.2	9.9	11.4
10	12.0	11.8	10.6	11.9	9.5	7.2	6.0	8.7	16.1	10.8	10.0	11.5
11	16.1	11.8	10.6	11.7	9.5	7.5	5.9	12.0	16.0	11.7	10.2	11.4
12	13.1	11.8	10.6	11.7	9.2	8.2	6.0	12.0	15.8	72.1a	10.5	11.3
13	12.2	11.8	10.7	11.0	9.6	8.1	5.9	12.2	15.3	12.4	10.9	11.2
14	12.0	11.6	10.7	10.6	9.5	7.8	5.9	12.1	15.4	13.5	11.0	11.1
15	11.9	11.5	10.7	10.6	9.8	.....	6.0	12.3	16.0	12.7	11.3	11.2
16	12.0	11.5	15.3	10.7	9.4	7.6	6.0	12.3	15.5	13.0	11.7	12.9
17	12.0	11.5	14.7	10.6	9.4	7.8	5.8	12.2	15.3	13.0	11.5	11.8
18	12.0	11.3	13.7	10.7	9.4	7.9	5.4	12.6	14.3	12.3	12.0	11.8
19	11.9	11.4	12.3	10.2	9.7	7.7	5.6	13.0	15.7	12.0	11.9	11.6
20	11.8	11.3	13.7	10.8	9.8	7.3	5.6	13.0	14.9	11.4	11.8	11.6
21	11.7	11.3	13.1	9.9	9.5	7.5	5.8	12.5	15.2	11.2	12.2	11.3
22	11.8	11.3	12.9	9.9	9.4	7.6	7.2	12.4	16.1	11.6	12.7	11.1
23	11.7	11.3	12.8	10.3	9.4	7.4	8.6	12.4	10.8	11.9	12.1	11.1
24	11.6	11.3	13.2	10.6	9.2	7.1	9.3	12.5	10.4	10.3	12.0	11.1
25	11.6	11.4	14.3	10.5	9.2	7.2	8.9	12.4	10.3	10.7	13.3	10.9
26	11.6	11.4	13.5	10.4	9.0	7.4	9.2	12.6	10.3	11.4	11.7	11.2
27	11.6	11.3	13.4	10.4	9.0	7.3	9.4	12.5	10.5	11.3	11.5	11.1
28	11.6	11.3	13.6	10.4	9.0	7.2	9.5	12.2	10.5	11.1	11.5	11.1
29	11.6	.....	13.6	11.0	9.4	6.7	9.7	12.3	10.6	11.0	11.4	11.2
30	11.6	.....	13.5	11.2	9.3	6.4	9.6	12.2	10.6	11.4	11.2	11.1
31	11.7	.....	13.5	.....	.....	.....	10.0	12.1	.....	11.3	.....	11.3
Mean	11.9	11.7	12.2	10.8	9.8	8.1	7.1	11.8	14.3	13.3	11.2	11.3

a Rain in mountains.

SANTA ANA RIVER AT WARMSPRINGS, CALIFORNIA.

This river has its source on the southern slope of the San Bernardino Mountains and flows southerly, appearing from its canyon 4 miles north of Redlands. Its waters are completely used in San Bernardino Valley. At the lower part of the valley the water appears again in the vicinity of Rincon, where the river passes through a comparatively narrow gorge, and the general direction of the stream is thence southwesterly, emptying into the Pacific Ocean. The station, established June, 1896, is located 5 miles northeast of Mentone, California, three-fourths of a mile below the headworks of the Santa Ana canal and opposite the warm springs in the canyon. The gage is an inclined timber fastened to a large bowlder and posts set in the bank of the river. On October 16, 1898, owing to some local legal complications, an unusually large volume of water was turned into the Santa Ana canal by the Bear Valley Company. This water was wasted from the canal at a point below the old gage rod, necessitating the establishment of a new gage rod upon this stream at a point below where the waste from the canal was turned into the river. The new gage was put in November 9, 1898, and since that date daily observations have been kept on the lower gage, which is a 2 by 6 inch timber firmly bolted to a granite cliff which forms the left bank of the river, and is situated 800 feet below the mouth of Warmsprings Canyon and 100 feet above a ford on the canyon road. A landslide occurred below the gage rod April 16, 1899, which changed the condition of the rating for the station. Owing to the shifting nature of the stream bed it has not been possible to construct perfectly satisfactory rating curves, but the tables as presented are based on the best information that could be obtained. The record is not considered absolutely correct, but is given as an approximation. This river is one of the most difficult streams in the State of which to obtain an accurate record. The Edison Electric Company diverts the greater portion of the water of Santa Ana River above the gaging station, but also returns all of it above the station; they, however, allow only limited portions of the water to pass out of their conduits during certain hours of the day, holding back the water for the purpose of obtaining additional power when the greatest demand exists. An effort is being made to arrange with this company to obtain a record of the number of gates, the sizes of the openings, and the hours at which the various wheels are run, in order to more accurately determine the volumes of water. The Santa Ana canal, as mentioned above, also diverts water from Santa Ana River above the station, but the greater part of it is returned to the channel of the stream before passing the point of measurement. A portion, as indicated by the measurements below, passes down the canal. Results of measurements may be found as follows: 1896, Eighteenth Annual Report, Part IV, page 411; 1898,

Twentieth Annual Report, Part IV, page 554. A number of measurements of discharge of the canals diverting water from Santa Ana River at the mouth of the canyon were made by S. G. Bennett, and are given below. The following measurements were made at the main station under the direction of J. B. Lippincott in 1899:

Discharge measurements of Santa Ana River at Warmsprings, California.

1899.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
January 12	2.34	38.00	May 31	2.27	21.00
February 18	2.16	28.04	June 15	2.21	19.60
March 23	2.30	29.62	July 15	2.30	25.90
May 6	2.45	25.84	August 24	1.85	10.86

Rating table for Santa Ana River at Warmsprings, California, applicable from January 1 to April 15, 1899.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.8	12.5	2.1	21.5	2.3	34.0
1.9	15.0	2.2	26.5	2.4	48.0
2.0	18.0				

Rating table for Santa Ana River at Warmsprings, California, applicable from April 16 to December 31, 1899.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.7	8.0	2.2	19.0	2.7	36.0
1.8	10.0	2.3	22.0	2.8	41.0
1.9	12.0	2.4	25.0	2.9	46.5
2.0	14.0	2.5	28.5	3.0	52.5
2.1	16.5	2.6	32.0		

Discharge measurements of Santa Ana canal, California.

1899.

Date.	Discharge.	Date.	Discharge.
	Second-feet.		*Second-feet.*
January 12	.....	May 31	1.10
February 18	4.00	June 15	.20
March 23	7.60	July 15	.....
May 6	3.40	August 24	.....

Discharge measurements of canals diverting water from Santa Ana River at mouth of canyon, California.

Date.	Canal.	Discharge.
1899.		*Second-feet.*
February 18	North Fork or Highland ditch	8.07
February 18	South Fork or Redlands ditch	15.70
February 18	Green Spot pipe line	.35
March 23	North Fork or Highland ditch	11.78
March 23	South Fork or Redlands ditch	17
March 23	Green Spot pipe line	3.71
May 6	North Fork or Highland ditch	7.70
May 6	South Fork or Redlands ditch	15.50
May 6	Green Spot pipe line	1.43
May 31	North Fork or Highland ditch	6.74
May 31	South Fork or Redlands ditch	14.67
May 31	Green Spot pipe line	.14
June 15	North Fork or Highland ditch	10.30
June 15	Morton Canyon water	.17
June 15	Redlands tunnel water at point where it reaches South Fork ditch.	.67
June 15	South Fork or Redlands ditch at flume above sand box.	7.76
June 15	Head of Green Spot pipe line	.08
July 12	South Fork or Redlands ditch	11.50
July 15	North Fork or Highland ditch	13.14
July 15	Morton Canyon water	.12
July 15	Redlands tunnel	1.03
July 15	South Fork or Redlands ditch	12.70
July 15	Head of Green Spot pipe line.	.59

Daily gage height, in feet, of Santa Ana River at Warmsprings, California, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	2.10	2.20	2.20	2.30	2.35	2.65	2.30	2.20	1.90	1.90	2.20	2.35
2	2.10	2.25	2.20	2.20	2.30	2.35	2.30	2.20	1.90	1.90	2.20	2.24
3	2.10	2.25	2.20	2.15	2.30	2.40	2.30	2.20	1.90	1.90	2.20	2.24
4	2.10	2.25	2.20	2.20	2.35	2.35	2.30	2.00	1.90	1.90	2.20	2.26
5	2.10	2.20	2.20	2.20	2.40	2.30	2.30	2.00	1.90	1.90	2.11	2.20
6	2.10	2.20	2.20	2.20	2.45	2.30	2.35	2.00	1.90	1.90	2.12	2.17
7	2.10	2.20	2.20	2.20	2.45	2.30	2.35	1.90	1.90	2.00	2,15	2.18
8	2.10	2.20	2.20	2.20	2.35	2.30	2.35	1.90	1.90	1.95	2.16	2.15
9	2.10	2.20	2.20	2.15	2.25	2.30	2.35	1.90	1.90	1.95	2.15	2.22
10	2.10	2.20	2.20	2.15	2.25	2.25	2.37	1.90	1.90	1.90	2.15	2.27
11	2.30	2.20	2.20	2.15	2.30	2.25	2.37	1.90	1.90	1.90	2.15	2.16
12	2.30	2.20	2.20	2.15	2.30	2.25	2.35	1.90	1.90	1.90	2.12	2.25
13	2.30	2.20	2.15	2.15	2.35	2.30	2.35	1.90	1.90	2.20	2.17	2.25
14	2.30	2.20	2.15	2.10	2.35	2.30	2.35	1.90	1.90	2.20	2.15	2.25
15	2.20	2.20	2.15	2.10	2.30	2.30	2.30	1.90	1.90	2.15	2.61	2.25
16	2.20	2.20	2.20	2.40	2.30	2.25	2.30	1.90	1.90	2.15	2.19	2.25
17	2.20	2.20	2.25	2.35	2.30	2.30	2.30	1.90	1.90	2.15	2.30	2.51
18	2.20	2.20	2.35	2.35	2.25	2.30	2.30	1.90	1.80	2.15	2.44	2.47
19	2.20	2.20	2.30	2.35	2.25	2.20	2.30	1.90	1.80	2.17	2.24	2.48
20	2.20	2.20	2.55	2.30	2.25	2.30	2.25	1.87	1.80	2.17	2.29	2.44
21	2.20	2.20	2.55	2.30	2.30	2.30	2.20	1.87	1.80	2.17	2.26	2.37
22	2.20	2.20	2.30	2.30	2.20	2.25	2.25	1.87	1.80	2.17	2.95	2.49
23	2.20	2.20	2.30	2.30	2.25	2.25	2.25	1.87	1.85	2.17	2.51	2.71
24	2.20	2.30	2.35	2.35	2.30	2.25	2.25	1.87	1.85	2.17	2.24	2.64
25	2.20	2.20	2.35	2.40	2.30	2.30	2.50	1.90	1.85	2.20	2.30	2.22
26	2.20	2.25	2.35	2.40	2.30	2.35	2.50	1.90	1.90	2.20	2.26	2.34
27	2.20	2.20	2.40	2.40	2.25	2.30	2.30	1.90	1.90	2.20	2.33	2.36
28	2.20	2.20	2.35	2.40	2.30	2.30	2.27	1.90	1.90	2.20	2.25	2.40
29	2.20	.....	2,35	2.40	2.30	2.28	2.25	1.90	1.90	2.20	2.25	2.39
30	2.20	.....	2.35	2.35	2.30	2.28	2.20	1.90	1.90	2.20	2.25	2.34
31	2.20	.....	2.30	.....	2.30	.....	2.20	1.90	.....	2.20	.....	2.47

MILL CREEK IN CANYON, CALIFORNIA.

This stream is one of the larger tributaries of Santa Ana River, although on account of its importance for irrigation it is generally considered as an independent stream. It rises on the western slope of the San Bernardino Mountains, draining the area immediately south of the headwaters of Santa Ana River. Mill Creek appears from its canyon about 5 miles east of Redlands. The Crafton Water Company diverts all of the water of this creek at the mouth of the canyon, particularly in the summer. The water passes over a weir, and the volume is therefore determined with considerable accuracy. The records have been furnished to this office by Mr. Herbert Garstine, president of the Crafton Water Company. They are particularly accurate for low-water measurements. This stream is described in detail in the Nineteenth Annual Report, Part IV, page 551. The first table gives the measurements made by S. G. Bennett near the head of Crafton zanja in 1899. The second table shows the discharge of Mill Creek, as furnished by the Crafton Water Company, at the head of Crafton zanja during the irrigation seasons of 1897, 1898, and 1899.

Discharge measurements near head of Crafton zanja, California.

1899.

Date.	Discharge.	Date.	Discharge.
	Second-feet.		*Second-feet.*
January 12	10.77	May 31	11.61
February 18	10.53	June 15	6.94
March 23	15.63	July 15	7.40
May 6	14.55	August 24	7.18

Discharge, in second-feet, of Mill Creek at head of Crafton zanja, California.

1897.

Day.	July.	Aug.	Sept.	Oct.	Day.	July.	Aug.	Sept.	Oct.	Day.	July.	Aug.	Sept.	Oct.
1	.....	21	22	18	12	24	20	18	16	22	.....	22	27	.....
2	.....	23	22	18	13	24	20	18	15	23	.....	21	19	.....
3	.....	24	22	19	14	.....	20	18	15	24	.....	21	16	.....
4	.....	24	21	19	15	.....	20	18	18	25	.....	22	19	.....
5	.....	24	20	17	16	.....	19	19	18	26	28	21	19	.....
6	.....	21	20	21	17	.....	19	16	18	27	22	21	18	.....
7	.....	22	19	19	18	.....	24	17	18	28	27	20	18	.....
8	.....	22	19	19	19	.....	26	18	20	29	27	20	19	.....
9	.....	22	18	19	20	.....	24	19	18	30	24	20	19	.....
10	.....	19	18	18	21	.....	24	20	18	31	24	20	.....	.....
11	.....	19	18	16										

Discharge, in second-feet, of Mill Creek at head of Crafton zanja, California—Continued.

1898.

Day.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	17	26	16	11	8	9	9	10	10
2	.....	17	22	16	10	8	9	9	10	10
3	.....	17	17	16	10	8	7	9	10	10
4	.....	17	17	16	11	8	9	9	10	10
5	.....	17	16	16	11	8	8	9	10	10
6	.....	17	17	14	11	7	9	9	10	10
7	.....	17	17	12	11	7	8	9	10	10
8	.....	17	17	14	10	7	8	9	10	10
9	.....	17	17	14	10	7	8	9	10	10
10	.....	17	15	15	8	a10	8	9	10	11
11	.....	16	15	14	8	10	8	9	10	11
12	.....	17	15	14	10	8	7	9	10	11
13	.....	17	15	14	10	8	8	9	10	11
14	.....	18	15	13	10	7	8	9	10	11
15	.....	18	18	13	9	7	8	9	10	12
16	.....	17	18	13	9	7	7	9	10	11
17	.....	17	18	12	9	7	8	9	10	12
18	.....	17	18	15	8	7	8	9	10	11
19	.....	17	20	12	9	7	8	9	10	11
20	.....	17	18	12	9	11	8	9	10	11
21	17	17	17	13	9	25	8	9	10	11
22	.....	17	16	12	9	17	8	9	10	11
23	.....	17	16	13	9	14	8	9	10	10
24	.....	17	18	12	8	10	8	8	10	10
25	18	16	16	12	7	10	9	9	10	11
26	18	16	16	11	9	9	9	8	10	11
27	17	15	18	11	7	9	9	9	10	10
28	17	16	18	11	7	13	9	9	10	11
29	17	19	17	10	7	13	8	9	10	11
30	17	19	16	10	8	11	9	10	10	11
31	17	.....	16	.....	7	11	.....	10	.....	11

a Not entire flow of creek.

1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	11	11	11	13	12	17	5.6	7.1	5.5	4.8	7.2	9.8
2	11	11	11	13	11	13	6.2	6.2	5.6	5.3	7.2	9.5
3	11	11	11	12	11	12	6.2	5.8	5.4	5.3	6.8	9.4
4	11	11	11	12	11	11	6.2	6.7	5.4	4.3	6.8	8.8
5	11	11	11	12	11	10	4.9	7.2	5.5	4.6	7.2	8.0
6	12	11	11	11	11	11	6.7	6.9	5.6	6.3	7.2	7.8
7	11	11	11	12	12	10	6.7	6.7	5.6	5.6	7.2	8.0
8	10	11	11	12	12	10	6.7	6.2	5.3	4.8	7.2	5.3
9	11	12	11	12	12	10	6.7	6.2	5.7	5.6	6.1	9.0
10	.....	12	.....	12	12	8	6.2	6.2	5.3	5.2	6.1	8.8
11	.....	12	10	12	12	8	6.2	6.2	5.3	5.7	6.8	9.0
12	.....	12	10	11	12	8	6.2	6.2	4.9	6.1	6.8	8.2
13	.....	.....	10	11	12	8	4.8	5.6	4.9	6.2	6.4	9.8
14	.....	12	10	11	11	7	4.8	5.3	4.9	8.5	11.2	9.6
15	.....	12	10	11	12	7	5.1	6.2	5.2	7.8	11.2	9.6
16	.....	12	10	12	12	8	7.2	5.6	4.8	7.8	9.5	7.8
17	.....	.....	13	12	12	9	6.3	5.3	3.2	7.8	9.8	14.6
18	.....	12	13	13	11	8	4.9	6.0	3.0	7.2	9.8	13.0
19	.....	12	11	12	11	8	6.2	6.0	3.0	7.8	9.8	12.6
20	.....	12	15	11	11	8	4.9	5.3	2.8	7.2	9.7	9.8
21	.....	.....	14	11	11	8	5.1	5.9	2.8	7.2	9.7	9.4
22	.....	11	12	12	11	8	5.8	5.9	2.8	7.2	9.6	11.0
23	.....	11	12	11	11	7	6.2	5.3	2.8	7.8	9.7	9.6
24	.....	13	16	12	10	7	6.5	5.2	2.8	6.6	9.8	9.8
25	.....	11	16	12	10	7	5.4	5.3	2.8	6.6	10.4	9.8
26	.....	12	16	12	10	8	5.4	5.3	2.8	7.8	10.0	10.0
27	.....	12	12	12	11	8	4.8	5.8	2.9	7.2	9.8	10.0
28	.....	11	12	12	10	7	4.8	4.3	2.0	7.2	9.8	8.5
29	.....	.....	16	12	11	6	5.5	4.3	2.7	7.2	9.8	9.4
30	.....	.....	16	12	11	4	5.5	5.3	2.8	7.2	9.8	9.8
31	.....	.....	14	.....	11	.....	5.5	2.9	.....	7.2	.....	10.0

DEVELOPED WATER OF SAN BERNARDINO VALLEY, CALIFORNIA.

The streams of the eastern end of San Bernardino Valley are discharged from their mountain canyons on a delta-like formation of gravel and sand, into which the water rapidly sinks. Apparently a dike of impervious material extends across this valley in a northwest-southeast direction, passing a short distance east of the town of Colton. Into this body of undergound water numerous development works have been projected, and it is this source of supply which furnishes water for irrigation, particularly in the neighborhood of Riverside. Observations were instituted in 1898 to determine the total output from this underground source, and results may be found in the Twentieth Annual Report, Part IV, pages 557 and 559. Similar observations were made for the Geological Survey by Mr. K. Sanborn, in March, June, and August, 1899, in order to discover whether there is a difference in output at the end of the rainy season as compared with the end of the dry season, and whether the supply is increasing or decreasing. The following table gives the three series of measurements in 1899:

Discharge measurements in San Bernardino Valley, California.

Date.	Stream.	Ditch.	Discharge.
1899.			*Second-feet.*
February 28 ..	Warm Creek.....	Upper canal, Riverside Water Company, at head gate.	60.53
Do.....	.....do	Swamp, at first turnout	.85
Do.....	Santa Ana River ...	Mill flume, Riverside Water Company, end of flume.	5.30
March 1.....	Lytle Creek.....	Whitings, head.....	.76
Do.....	.....do	McIntyre, head	.82
Do.....	City Creek.....	Whitlock, flume at Waterman avenue.	.47
Do.....	.....do	Logsdon & Farrell, at head ...	1.61
Do.....	.....do	Daley, at head.....	.71
Do.....	Warm Creek.....	Meeks & Daley, at head gate..	17.00
March 2.....	.....do	Haws & Talmage, at head gate.	.28
Do.....	.....do	Beam, flume at head.....	.72
Do.....	.....do	Rabel, at head gate	2.26
Do.....	.....do	Shay or Stout dam, at head gate.	2.23
Do.....	.....do	McKenzie, 300 feet below head gate.	9.40
March 7.....	Santa Ana River ...	Gage canal, head	.72
Do.....	.....do	Gage canal, Palm avenue, weir.	27.40
Do.....	.....do	Timber, at head	.00
Do.....	Artesian wells	Camp Carlton	2.13
March 10.....	Santa Ana River ...	Lower canal, Riverside Water Company, Spanishtown ditch turnout.	16.00
Do.....	.....do	Ward & Warren, at head.....	3.09
Do.....	Artesian wells	Wells, Riverside Water Company.	16.57
March 13.....	Lytle Creek.....	Ranchero, near head.....	1.64

Discharge measurements in San Bernardino Valley, California—Continued.

Date.	Stream.	Ditch.	Discharge.
1899.			*Second-feet.*
March 13	Pumping plants	East Riverside irrigation district, at reservoir.	4.25
Do	do	Colton Terrace Water Company, head of pipe line.	1.69
Do	do	City of Colton	.00
Do	do	Pomeroy & Marble	.00
Do	do	Johnson & Hubbard	.00
Do	do	Base line and Waterman avenue.	.00
March 25	City Creek	In canyon above all diversions.	8.80
June 16	Warm Creek	Haws & Talmage, 300 feet below head.	.05
Do	do	Rabel, weir at head	1.54
Do	do	Shay or Stout dam, weir at head submerged.	1.13
Do	do	McKenzie, 150 feet below head gate.	3.86
June 20	do	Swamp, weir first turnout	.77
Do	Santa Ana River	Gage canal, weir at head	.24
Do	do	Gage canal, Palm avenue, weir.	25.46
Do	do	Timber, head	.00
Do	do	Ward & Warren, weir at head	.62
Do	do	Camp Carlton, weir at head	1.62
June 23	Lytle Creek	McIntyre, weir at head	.15
Do	Pumping plants	East Riverside irrigation district, weir to reservoir.	2.08
Do	do	Upper Bloomington, submerged weir near head.	3.34
Do	do	Lower Bloomington, submerged weir flume.	5.93
June 26	Warm Creek	Meeks & Daley, weir at head	15.48
Do	do	Upper canal, Riverside Water Company, weir at head.	53.92
Do	Santa Ana River	Mill flume, Riverside Water Company, flume at mill.	7.29
Do	Pumping plants	Colton Terrace Water Company, head of pipe line.	1.30
Do	do	City of Colton, weir, upper plant.	2.09
Do	do	City of Colton, estimated	2.60
Do	do	Mill pump, Riverside Water Company, weir at mill.	1.77
June 27	Warm Creek	Beam, flume at head	.52
Do	Lytle Creek	Whitings, weir at head	.26
Do	City Creek	Whitlock, flume, Stiles street	.28
Do	do	Logsdon & Farrell, flume at head.	1.15
Do	do	Daley, flume across City Creek	.51
June 28	Santa Ana River	Lower canal, Riverside Water Company, flume at head.	9.09
August 22	Warm Creek	McKenzie, 200 feet below head gate.	2.00
August 25	do	Haws & Talmage, head gate	.09
Do	do	Rabel, at head gate	.94
Do	do	Shay or Stout dam, weir at head.	.90
Do	do	Meeks & Daley, weir at head	10.45
Do	Santa Ana River	Gage canal, weir at head	.64
Do	do	Gage canal, Palm avenue, weir.	24.11
Do	do	Timber, head	.00

Discharge measurements in San Bernardino Valley, California—Continued.

Date.	Stream.	Ditch.	Discharge.
1899.			*Second-feet.*
August 26	Warm Creek	Beam, flume at head	.40
Do	Lytle Creek	McIntyre, head	.00
Do	do	Whitings, head	.01
Do	do	Ranchero, weir near head	.41
Do	Pumping plants	East Riverside irrigation district, pumps not running.	.00
Do	do	Colton Terrace Water Company	1.30
Do	do	City of Colton, upper pumps	1.52
Do	do	City of Colton, lower pumps	2.37
Do	do	Upper Bloomington, weir at head.	1.18
Do	do	Lower Bloomington, weir at flume.	3.05
Do	do	Pomeroy & Marble, not running.	.00
Do	do	Johnson & Hubbard, not running.	.00
Do	do	Base line and Waterman avenue, estimated by owner.	1.20
August 27	Santa Ana River	Camp Carlton, weir at head	1.02
August 28	City Creek	Whitlock, flume, Stiles street	.09
Do	do	Logsdon & Farrell, flume at head.	.54
Do	do	Daley, flume across City Creek	.51
August 30	Warm Creek	Swamp, weir first turnout	.69
Do	Santa Ana River	Ward & Warren, weir at head	1.56
Do	do	Mill flume, Riverside Water Company, flume at mill.	2.50
August 31	Pumping plants	Mill pump, Riverside Water Company, weir at pump.	1.67
Do	Warm Creek	Upper canal, Riverside Water Company, weir at head.	52.04
September 1	Santa Ana River	Lower canal, Riverside Water Company, flume at head.	7.38

TEMESCAL CREEK NEAR RINCON, CALIFORNIA.

This stream rises in the extreme southwestern corner of Riverside County, California. Its smaller tributaries have their sources on the eastern slope of the Santa Ana Mountains. The river flows in a general northerly direction, entering Santa Ana River 2½ miles above Rincon and just above the lower narrows of the Santa Ana. San Jacinto River discharges into Lake Elsinore. During years of heavy rainfall this lake overflows and the surplus water finds its way into Temescal Creek. During the last few years, however, there has been no such discharge from Lake Elsinore. The water of Temescal Creek and of its tributary, Coldwater Creek, is used for irrigation in the vicinity of Corona. A series of measurements of Temescal and Coldwater creeks have been made by F. Rolfe, and are given below. The first table gives the measurements at the upper pipe line of the Temescal Land and Water Company at the manhole in Rolfe's field; the second table shows the discharge of the lower pipe line at Eddy's blacksmith shop; the third table is the discharge of the same pipe line near

Riley's ranch; the fourth table shows the discharge of Coldwater Creek at its mouth.

During the recent dry years there has been no surface flow of Temescal Creek. The water flowing in the upper pipe line of the Temescal Land and Water Company includes the principal part of the flow of Coldwater Creek and Temescal Hot Springs, augmented by water pumped from wells in Temescal Valley.

Discharge measurements of upper pipe line of Temescal Land and Water Company at manhole in Rolfe's field, California.

1899.

Date.	Discharge.	Date.	Discharge.
	Second-feet.		*Second-feet.*
January 27	0.74	April 22	3.71
February 4	1.62	April 29	3.25
February 11	.87	May 6	2.80
February 18	3.67	May 13	4.02
February 24	3.37	May 18	4.21
March 3	3.87	May 30	4.01
March 12	5.10	June 9	3.36
March 16	3.56	June 16	3.53
March 25	3.74	July 10	3.21
March 31	4.16	July 19	3.20
April 14	2.98	July 25	3.67

Discharge measurements of lower pipe line of Temescal Land and Water Company, California.

1899.

Date.	Discharge.	Date.	Discharge.
	Second-feet.		*Second-feet.*
January 28	0.66 *a*	April 22	2.28 *a*
February 1	.00 *a*	April 29	2.28 *a*
February 11	.34 *a*	May 6	4.46 *a*
February 15	1.39 *a*	May 13	2.55 *a*
February 20	1.56 *a*	May 30	3.08 *b*
March 4	4.22 *a*	June 9	3.10 *b*
March 12	3.51 *a*	June 15	2.36 *b*
March 18	2.69 *a*	July 4	2.87 *b*
March 25	2.91 *a*	July 19	2.03 *b*
March 31	3.42 *a*	July 28	2.49 *b*
April 14	.89 *a*		

a Measurements at Eddy's blacksmith shop. *b* Measurements near Riley's ranch.

Discharge measurements of Coldwater Creek at mouth, California.

1899.

Date.	Discharge.	Date.	Discharge.
	Second-feet.		*Second-feet.*
January 18	1.43	April 15	0.62
January 27	.84	April 21	.26
February 3	.99	April 26	.38
February 11	.97	May 5	.37
February 18	.78	May 13	.21
February 24	.94	May 17	.21
March 1	.92	May 29	.27
March 12	.71	May 31	.38
March 17	1.60	May 31	.39
March 25	1.18	June 5	.20
March 31	.84	June 7	.22
April 14	.68		

CHINO CREEK AT RINCON, CALIFORNIA.

San Antonio Creek discharges from the southern slope of the Sierra Madre onto a large bed of sand and gravel. The underground waters percolate slowly to the south, and begin to appear again in the channel of what is known as Chino Creek. This creek enters Santa Ana River just before the latter stream passes through its lower canyon in the Coast Range. The discharge of Chino Creek is very constant, owing to the nature of its supply, and hence water rights along its course are valuable on account of their permanency. A series of measurements of the supply of this creek were made during 1899 under the direction of J. B. Lippincott. There is no gage rod, owing to the shifting nature of the stream bed.

Discharge measurements of Chino Creek at Rincon, California.

1899.

Date.	Discharge.	Date.	Discharge.
	Second-feet.		*Second-feet.*
May 2	12.79	August 15	2.14
May 15	8.64	August 31	3.19
June 3	17.02	September 29	3 88
June 15	5.63	October 25	14.52
July 4	3.02	October 26	14.52
July 17	4.68	November 18	20.06
August 1	7.49		

SANTA ANA RIVER AT RINCON, CALIFORNIA.

This river and its tributaries derive their water supply from the southern and western slopes of the San Bernardino Mountains. On their appearance from their canyons the water is shortly diverted for irrigation purposes. After passing through San Bernardino Valley water begins to appear on the lower courses of Santa Ana River, and at the point where it passes through the Coast Range a remarkably constant stream is found. The bed rock, although not visible in the channel of the river, must be near the surface, judging by the appearance of the water in the bed. Springs of large volume occur on the southern side of the river near Rincon, and the flat lands immediately above there are heavily saturated with the rising water. Artesian water also is found in considerable quantities from Rincon to Pomona, in the valley of Chino Creek. Twelve miles above Rincon Santa Ana River passes through what is known as Riverside Narrows, and here also the water appears at the surface. Approximately 80 second-feet are used in this locality for irrigation purposes. Two measurements were made at Riverside Narrows in 1899, the first, on July 17, showing a discharge of 31.70 second-feet, and the second, on September 12, showing a dis-

charge of 39.69 second-feet. Measurements were also made during 1899 of Santa Ana River at the Rincon Narrows. The first were made 1 mile below the town of Rincon, and included the water of Chino Creek. After September 29 measurements were made at the bridges in the town of Rincon and above the mouth of Chino Creek. It was found that at this latter point from 2 to 3 second-feet more water was flowing than at the locality 1 mile below, where the earlier measurements were made.

Discharge measurements of Santa Ana River near Rincon, below mouth of Chino Creek, California.

Date.	Discharge in second-feet.		
	River.	Canal.	Total.
1898.			
June 21	79.81	3.18	82.99
August 28	62.67	4.15	66.82
1899.			
January 3	209.40	2.30	211.70
January 16	231.90	.....	231.90
January 28	216.00	6.50	222.50
February 15	181.00	1.75	182.75
March 4	108.60	0.00	108.60
March 18	199.89	0.00	199.89
April 6	172.23	0.00	172.23
April 18	101.10	2.75	103.85
May 2	100.34	2.45	102.79
May 15	100.86	3.95	104.31
June 3	110.27	3.18	113.45
June 16	87.89	1.65	89.54
July 4	68.89	2.42	71.31
July 18	64.13	1.54	65.67
August 1	57.82	3.44	61.26
August 15	64.71	3.16	67.87
August 30	65.90	2.00	67.90
September 13	72.73	1.65	74.38
September 29	83.82	.....	83.82

Discharge measurements of Santa Ana River at Rincon, above mouth of Chino Creek, California.

1899.

Date.	Discharge in second-feet.			
	River.	Chino Creek.	Springs.	Total.
October 25	131.32	14.52	0.50	146.34
October 26	146.58	14.52	.50	161.55
November 18	151.16	20.06	.50	171.72

SAN LUIS REY RIVER, CALIFORNIA.

This river rises on the western slope of the Coast Range, in the northern part of San Diego County, California. It flows westerly, with rapid fall, and after passing through a narrow gap in the mountains finally enters the Pacific about 35 miles north of San Diego. The water of this river is diverted upon its appearance from the canyon by the flume of the Escondido irrigation district, and is conducted to a reservoir, whence its waters are used for irrigation purposes. In

addition to this diversion, 2 second-feet, approximately, are permitted to remain in the river for the use of the Indians near Pauma, who are prior appropriators. The following results are furnished by the Escondido irrigation district. The measurements are made over a weir at the headworks of their canal. The following table shows the entire flow of the river, with the exception of the 2 second-feet noted above. The drainage area at the point of diversion is 229 square miles.

Discharge, in second-feet, of San Luis Rey River in canyon, California, for 1899.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.0	8.0	5.6	10.9	*a*	10.0	*a*	*a*	*a*	*a*	0.0	0.0
2	0.0	20.0	5.3	9.3	.....	10.0	.....	.....	.....	.....	0.0	0.0
3	0.0	33.0	5.0	9.0	.....	0.0	.....	.....	.....	.....	0.0	0.0
4	0.0	18.3	4.7	8.6	.....	0.0	.....	.....	.....	.....	0.0	0.0
5	0.0	14.9	4.1	8.1	.....	0.0	.....	.....	.....	.....	0.0	0.0
6	0.0	10.1	3.6	7.8	.....	0.0	.....	.....	.....	.....	0.0	0.0
7	0.0	10.2	3.6	7.3	.....	0.0	.....	.....	.....	.....	0.0	0.0
8	0.0	10.2	3.6	6.5	.....	0.0	.....	.....	.....	.....	0.0	0.0
9	0.0	9.3	3.6	6.2	.....	0.0	.....	.....	.....	.....	0.0	0.0
10	0.0	9.0	3.6	5.9	.....	0.0	.....	.....	.....	.....	0.0	0.0
11	24.0	8.6	3.6	5.3	.....	0.0	.....	.....	.....	.....	0.0	0.0
12	0.0	7.8	3.6	4.9	.....	0.0	.....	.....	.....	.....	0.0	0.0
13	0.0	7.8	3.6	4.6	.....	0.0	.....	.....	.....	.....	0.0	0.0
14	10.0	7.8	3.6	4.4	.....	0.0	.....	.....	.....	.....	0.0	0.0
15	0.0	7.8	3.6	4.1	.....	0.0	.....	.....	.....	.....	0.0	0.0
16	6.0	7.3	3.6	3.9	.....	0.0	.....	.....	.....	.....	0.0	2.0
17	6.0	6.9	24.4	3.6	.....	0.0	.....	.....	.....	.....	0.0	0.0
18	6.0	5.9	24.4	0.0	.....	0.0	.....	.....	.....	.....	0.0	4.8
19	5.6	5.6	11.7	0.0	.....	0.0	.....	.....	.....	.....	0.0	3.6
20	5.3	5.3	11.7	0.0	.....	0.0	.....	.....	.....	.....	0.0	0.0
21	4.9	4.9	25.0	0.0	.....	0.0	.....	.....	.....	.....	0.0	0.0
22	4.7	4.7	18.5	0.0	.....	0.0	.....	.....	.....	.....	0.0	0.0
23	3.0	4.7	13.3	0.0	.....	0.0	.....	.....	.....	.....	3.0	0.0
24	3.6	16.8	11.7	0.0	.....	0.0	.....	.....	.....	.....	0.0	0.0
25	3.6	10.1	10.9	0.0	.....	0.0	.....	.....	.....	.....	0.0	2.6
26	3.6	7.5	19.5	4.7	.....	0.0	.....	.....	.....	.....	0.0	0.0
27	3.4	6.6	11.7	4.1	.....	0.0	.....	.....	.....	.....	0.0	0.0
28	3.0	5.9	10.9	0.0	.....	0.0	.....	.....	.....	.....	0.0	0.0
29	3.0	.....	17.8	0.0	.....	0.0	.....	.....	.....	.....	0.0	0.0
30	3.0	.....	15.1	0.0	.....	0.0	.....	.....	.....	.....	0.0	7.2
31	3.0	.....	11.7	.....	.....	.....	.....	.....	.....	.....	.....	5.4

a River dry for month.

SWEETWATER RIVER AT SWEETWATER DAM, CALIFORNIA.

This river has its source on the western slope of the Cuyamaca Mountains, in the extreme southern part of San Diego County, California, adjoining Mexico. During the last three seasons observations of the discharge of this river into the Sweetwater reservoir have been made by N. H. Savage, who is the chief engineer of the Sweetwater irrigation system. The measurements are of particular accuracy, because the capacity of the reservoir is definitely known, and the readings of the gage rod in the reservoir indicate volumes discharged. Mr. Savage furnishes these records voluntarily, and they are of special interest, not only because of the great value of water in this portion of San Diego County, but also because this basin is located in the extreme southwestern corner of the United States. The effects of the severe drought of the last few years in southern California are brought out

very plainly by a study of the discharge table which is given below. The drainage area above the reservoir is 186 square miles. The second table shows the amount of evaporation, by weeks, from the water surface of the Sweetwater reservoir, from January 1, 1897, to April 30, 1899. The third table shows the rainfall for 1898.

Estimated discharge of Sweetwater River at Sweetwater dam, California.

[Drainage area, 186 square miles.]

Year.	Discharge.	Total for year.	Run-off.		Rain.
	Sec. feet.	*Acre-feet.*	*Inches.*	*Sec. feet.*	
1896–97	9.35	6,777	0.665	0.050	10.97
1897–98	.006	4.3	.0005	.000082	7.05
1898–99	.339	245.5	.025	.0018	5.05

Evaporation at Sweetwater dam, California.

1897.

Date.	Weekly.	Monthly.	Date.	Weekly.	Monthly.
	Inches.	*Inches.*		*Inches.*	*Inches.*
January 1 to June 30		25.177	October 10	1.312	
July 4	.773		October 17	1.066	
	1.081		October 24	.984	
July 11	1.722		October 31	1.312	
July 18	1.724		November 7	.902	5.272
July 25	1.968		November 14	1.025	
August 1	1.617	8.062	November 21	1.148	
	.269		November 28	.920	
August 8	1.886		December 5	.234	4.229
August 15	1.845			.586	
August 22	1.783		December 12	.574	
August 29	1.722		December 19	.492	
September 5	.492	7.997	December 26	.492	
	1.230		December 31	.631	2.775
September 12	1.640				
September 19	1.476		Total for 1897		60.048
September 26	1.394				
October 3	.796	6.536			
	.598				

Records for three days in August were assumed; high winds filled pan.

Evaporation at Sweetwater dam, California—Continued.

1898.

Date.	Weekly.	Monthly.	Date.	Weekly.	Monthly.
	Inches.	*Inches.*		*Inches.*	*Inches.*
January 2	a 0.631		July 10	1.722	
	.107		July 17	1.968	
January 9	.328		July 24	1.804	
January 16	.246		July 31	1.886	
January 23	.492		August 7	1.804	8.153
January 30	.574		August 14	1.804	
February 7	.41	1.747	August 21	1.886	
February 13	.574		August 28	1.804	
February 20	.82		September 4	.843	8.141
February 27	.730			1.125	
March 6	.129	2.671	September 11	1.722	
	.773		September 18	1.804	
March 13	.738		September 25	1.599	
March 20	.82		October 2	.989	7.239
March 27	1.248			.395	
April 3	.670	4.249	October 9	1.230	
	.519		October 16	1.189	
April 10	1.066		October 23	1.025	
April 17	1.148		October 30	.984	
April 24	1.353		November 6	.176	4.999
May 1	1.265	5.351		1.054	
	.211		November 13	1.066	
May 8	1.230		November 20	.820	
May 15	1.23		November 27	.738	
May 22	1.066		December 4	.334	4.012
May 29	1.894			.445	
June 5	.480	5.611	December 11	No record.	
	1.201		December 18	No record.	
June 12	1.640		December 25	No record.	
June 19	1.517		December 31	.422	.867
June 26	1.804				
July 3	1.031	7.193	Total for 1898		60.233
	.773				

a Evaporation during last five days in 1897. Record missing for three weeks in December.

1899.

January 1	a 0.422		March 12	1.23	
	.070		March 19	.902	
January 8	.328		March 26	.656	
January 15	.246		April 2	.878	4.366
January 22	.533			.352	
January 29	.820		April 9	1.148	
February 5	.165	2.162	April 16	1.230	
	.411		April 23	1.886	
February 12	.656		April 30	1.312	5.928
February 19	.802				
February 26	.820		Total for 1899, to April 30		15.426
March 5	.281	2.970			
	.703				

a Evaporation during last six days in 1898.

Rainfall at Sweetwater dam, California.

Month.	1898.	1899.	Month.	1898.	1899.
	Inches.	*Inches.*		*Inches.*	*Inches.*
January	2.33	2.40	August	0.00	.00
February	.18	.70	September	0.00	.00
March	1.50	.89	October	0.00	.41
April	.33	.23	November	0.07	1.66
May	.85	.11	December	0.76	.77
June	0.00	.58			
July	0.00	.00	Total	5.97	7.77

MISCELLANEOUS DISCHARGE MEASUREMENTS IN CALIFORNIA.

During the severe drought of 1898 measurements on the important irrigation streams of California during their low stages were instituted, and the results were shown in Water-Supply Paper No. 28, page 193. The rainfall for 1899 was also deficient throughout California, and up to the present time the water shortage has been extreme. As a continuation of the low-water measurements of the previous years the series given below were made during 1899:

Miscellaneous discharge measurements in California in 1899.

Date.	Stream.	Locality.	Discharge.
			Second-feet.
January 11	Eaton Canyon Creek	At falls	0.50
March 14	Piru Creek	Narrows, 8½ miles above Piru.	3.52
March 15	Sespe Creek	Headworks of Sespe Land and Water Company's canal.	8.25
Do	Lower Cienega ditch	In Santa Clara Valley, 1 mile east of Fillmore.	2.43
March 16	Piru Creek	Just above wagon-road crossing, 200 feet below Southern Pacific Railroad bridge.	60.60
March 17	do	do	151.50
March 24	East Twin Creek	15 feet above headworks of Del Rosa canal.	3.88
Do	West Twin Creek	At point above headworks of canal.	3.00
March 25	Plunge Creek	At point below intake in walled canal.	10.85
September 13	Sacramento River	Jellys Ferry	4,087.00
September 16	American River	1 mile above mouth of South Fork.	86.10
Do	do	North Fork ditch, at road crossing 2½ miles above Folsom.	19.64
Do	do	Natoma ditch, South Fork, at Placerville road crossing.	20.00
Do	do	South Fork, estimated by Mr. Knight, superintendent Folsom Electric Power Company.	20.00
September 15	Sutter Creek	At town of Suttercreek, estimated.	1.00
Do	Cosumne River	At bridge, Jackson and Latrobe road crossing.	2.00
Do	do	Ditch, south side, at bridge, Jackson and Latrobe road crossing.	2.00
September 14	Mokelumne River	100 feet below bridge, Mock Hill, Jackson road.	33.10
Do	Calaveras River	Bridge, San Andres and Jackson road.	0.00
September 9	Stanislaus River	Oakdale	88.40
September 11	Tuolumne River	1,000 feet below gaging station, at bridge, Lagrange.	12.10
Do	do	Turlock canal, flume No. 3	28.90
Do	do	Mining ditch	24.00
		Total	65.00

Miscellaneous discharge measurements in California in 1899—Continued.

Date.	Stream.	Locality.	Discharge.
			Second-feet.
September 11	Merced River	Hoffman canal, 300 feet below head gate.	16.50
Do	do	1 mile above head gate, Hoffman canal.	35.50
Do	do	Valley Mills ditch	4.95
		Total	56.95
Do	do	Snellings ditch, estimated	0.50
September 8	San Joaquin River	Pollasky, 500 feet above bridge.	269.30
Do	do	Herndon	195.60
September 4	Kings River	Red Mountain	206.00
Do	do	Church ditch, at check weir just below Trimmer Springs road crossing.	151.10
Do	do	Fowler Switch canal, near mouth of canyon.	0.00
Do	do	Kingsburg canal, near mouth of canyon, estimated.	0.25
Do	do	Enterprise canal, near mouth of canyon, estimated.	2.00
Do	do	'76 canal, near mouth of canyon.	0.00
September 6	Kaweah River	Kaweah Irrigation and Power Company canal. This water is being pumped from wells.	1.49
Do	do	Pogues ditch	4.87
Do	do	One-half mile above headworks of Kaweah Irrigation and Power Company canal.	40.92
Do	do	North Fork	1.12
Do	do	South Fork, Britton ditch	0.41
Do	do	South Fork, estimated, Buttmann & Hitchcock ditch.	0.20
Do	do	South Fork, Carter's lower ditch.	0.32
Do	do	South Fork, estimated, Carter's upper ditch.	0.25
Do	do	At iron bridge	33.30
September 5	Tule River	Pioneer canal, just below headworks.	13.12
Do	do	Pioneer canal at road crossing, 1 mile below head gate.	8.43
Do	do	Pioneer canal at bridge road crossing, 2 miles below head gate.	7.06
September 2	Poso Creek		0.00
Do	Kern River	First point of measurement	99.22
September 5	Deer Creek		0.00
September 19	Santa Clara River	East channel, point where road crosses below San Francisquito Creek.	3.38
Do	do	West channel, below San Francisquito Creek.	1.65
Do	do	Newhall ditch	3.37
		Total	8.40

Miscellaneous discharge measurements in California in 1899—Continued.

Date.	Stream.	Locality.	Discharge.
			Second-feet.
August 19	Santa Clara River	Cumulos ranch ditch, 2 miles east of Cumulos ranch.	17.63
Do	do	2 miles east of Cumulos ranch house.	1.24
		Total	18.87
August 18	do	Farmers ditch	16.00
Do	do	Grease ditch	8.61
Do	do	East Side ditch	5.80
Do	do	Near Santa Paula	10.34
		Total	40.75
August 19	Piru Creek	Head of ditch of Piru Fruit Company.	1.33
August 18	Sespe Creek	In walled canal, Sespe Land and Water Company ditch.	1.93
Do	Santa Paula River	In flume 300 feet west of Nupu schoolhouse, 3 miles above Santa Paula.	0.85
August 21	Pacoima wash	Dry at mouth of canyon. Small spring from south side of mountain above wash, flowing 0.01, estimated.	0.00
Do	Pacoima submerged dam.	Pumping water which had accumulated during night. Man in charge of pump says they pump from 5 to 8 miners' inches per day.	0.24
Do	Little Tujunga River.		0.00
Do	Tujunga River	At weir headworks of Monte Vista ditch.	0.20
Do	do	Same place, statement of ditch tender.	0.44
August 28	San Gabriel River	Canals, statement H. F. Parkinson.	5.50
August 29	San Antonio Creek	Division weir, one-half to Pomona, one-half to Ontario.	4.06
Do	do	To Ontario	0.42
		Total	4.48
Do	Cucamonga Creek	Red Hill development, water goes to Ontario.	2.48
Do	Lytle Creek	Weir, head of Rialto canal	10.62
Do	do	Weir, head of Grapeland canal.	1.91
		Total	12.53
August 26	do	McIntyre ditch, at head	0.00
Do	do	Whitings ditch	0.01
Do	do	Ranchero ditch, weir near head.	0.41
August 25	Warm Creek	Haws & Talmage ditch, head gate.	0.00

Miscellaneous discharge measurements in California in 1899—Continued.

Date.	Stream.	Locality.	Discharge.
			Second-feet.
August 25	Warm Creek	Rabel ditch, head gate	0.94
Do	do	Shay or Stout ditch, weir at head.	0.90
August 22	do	McKenzie, 200 feet below head gate.	2.00
August 25	do	Meeks & Daley ditch, weir at head.	10.45
August 31	do	Upper canal, Riverside Water Company, weir at head.	52.04
August 26	do	Beam ditch, flume at head	0.40
August 30	do	Swamp ditch, weir, first turnout.	0.69
		Total of Warm Creek	67.42
August 28	City Creek	Whitlow ditch, flume, Stiles street.	0.09
Do	do	Logsdon & Farrell ditch, flume at head.	0.54
Do	do	Daley ditch, flume across City Creek.	0.51
August 25	Santa Ana River	Gage canal, weir, Santa Ana River.	0.64
Do	do	Gage canal, weir, Palm avenue.	24.11
Do	do	Timber ditch, at head	0.00
August 30	do	Ward & Warren ditch, weir at head.	1.56
Do	do	Mill flume, Riverside Water Company, flume at mill.	2.50
September 1	do	Lower canal, Riverside Water Company, flume at head.	7.38
August 27	do	Camp Carlton ditch, weir at head.	1.02
		Total	36.57
August 26	Pumping plants	East Riverside irrigation district, pumps not running.	0.00
Do	do	Colton Terrace Water Company.	1.30
Do	do	City of Colton ditch, upper pumps.	1.52
Do	do	City of Colton ditch, lower pumps.	2.37
Do	do	Upper Bloomington, weir at head.	1.18
Do	do	Lower Bloomington, weir at flume.	3.05
August 31	do	Mill pump, Riverside Water Company, weir at pump.	1.67
August 26	do	Pomeroy & Marble, not running.	0.00
Do	do	Johnson & Hubbard, not running.	0.00
Do	do	Base line and Waterman avenue, estimated by owner.	1.20
August 25	Santa Ana River	Developed and return water above Colton.	117.83
Do	Plunge Creek	In cement ditch below headworks in canyon.	0.48

Miscellaneous discharge measurements in California in 1899—Continued.

Date.	Stream.	Locality.	Discharge.
			Second-feet.
August 25	City Creek	In cement ditch near headworks in canyon.	0.17
Do	East Twin Creek	K. C. Investment Co., developed.	0.16
Do	do	Canal	0.58
Do	West Twin Creek	In V flume, at intake	0.20
August 24	Mill Creek	Old zanja	5.73
Do	do	Crafton headworks. This water is pumped from wells in bed of creek above Electric Co. power house.	1.45
		Total	7.18
Do	Santa Ana River	End of Green Spot pipe line	0.28
Do	do	South Fork ditch, Redlands canal, less amount from tunnel and Morton Canyon, 4.50 second-feet.	5.71
Do	do	Morton Canyon	0.11
Do	do	Redlands tunnel water	1.10
Do	do	Head of Green Spot pipe line	0.00
Do	do	North Fork ditch, Highlands canal, Cippoletti weir.	4.28
Do	do	Santa Ana canal	0.00
Do	do	Below overflow from Santa Ana canal.	10.86
August 30	do	Near Colton	0.00
Do	do	Submerged overflow, near Colton.	4.88
Do	do	West Riverside ditch	4.80
Do	do	Riverside Water Co., flume near Riverside Mesa tunnel.	57.39
Do	do	At Gallager Ford, just below Rubidoux Mountain.	5.63
Do	do	Chinese ditch	4.48
Do	do	At point 300 feet above Auburndale bridge, 3 miles north of Corona.	50.30
Do	do	South Side ditch	2.25
Do	do	North Side ditch	0.59
		Total at Auburndale	53.14
Do	do	1 mile below Rincon	65.90
Do	do	Scully ditch, or Bodieres, estimated.	2.00
		Total at gaging station	67.90
August 31	Chino Creek	Measured by F. Rolfe	3.19
Do	Santa Ana River	Santa Ana and Anaheim division box.	60.60
August 20	Water Canyon	Banning Colony, statement of C. D. Hamilton.	3.60
August 26	Cabazon ditch	At main road crossing	0.55
Do	Whitewater River	Two Cippoletti weirs at Bear Valley Irrigation Co. headworks.	6.34

PRECIPITATION ON MOUNTAINS IN SOUTHERN CALIFORNIA.

In order to obtain precipitation data bearing upon river discharge, a number of rain gages have been placed by Mr. J. B. Lippincott at various important points. The results obtained at these localities during 1899, together with a few figures from other sources, are shown in the following tables. The first gives the location of the rainfall station and the name of the observer, and the second the depth of rainfall, in inches, for each month of the year. Similar figures for 1896 are given on page 418 of the Eighteenth Annual Report, Part IV, for 1897 on page 539 of the Nineteenth Annual Report, Part IV, and for 1898 on page 560 of the Twentieth Annual Report, Part IV.

Location of rainfall stations in southern California.

Station.	Observer.	County.	Post-office.	Latitude.	Longitude.	Elevation.
				° ′	° ′	*Feet.*
Sisson	Southern Pacific R. R.	Siskiyou	Sisson	41 27	122 25	3,555
Redbluff	United States Weather Bureau.	Tehama	Redbluff	40 12	122 20	324
Sonora	Dr. John Shaw	Tuolumne	Sonora	38 00	120 16	1,824
Second Garrotte	J. P. Chamberlain	do	Groveland	37 49	120 12	2,900
Crockers	H. R. Crocker	do	Sequoia	37 48	119 53	4,453
Yosemite		Mariposa	Yosemite	37 45	119 35	4,063
Milo	R. T. Bailey	Tulare	Milo	36 15	118 50	3,200
Taylor's ranch	Geo. E. Carlton	Kern	Weldon	36 20	118 17	2,640
Kernville	Steven Barton	do	Isabella	35 45	118 25	2,600
Mount Breckenridge.	George Owens	do	Bakersfield	35 25	118 35	6,750
Tejon ranch	R. M. Pogsen	do	do	35 00	118 45	1,450
Fort Tejon	J. G. Stitt	do	Lebec	34 58	118 53	3,245
Bear Valley	Philip Tickert	do	Tehachapi			4,000
Glenn ranch	Jas. M. Applewhite	San Bernardino	Cajon	34 50	117 30	3,112
Frazier mine	N. Bennett	Ventura	Neenach	34 49	118 58	3,000
La Liebre	J. W. Forbes	Los Angeles	Neenach	34 46	118 40	3,170
Smith's ranch	William Smith	Ventura	Gorman	34 44	118 47	
Sneddens	Burt Snedden	do	Griffin	34 41	119 03	4,900
Mutah Flat	do	do	do	34 38	119 03	4,850
Palmdale headworks.	Burt Cole	Los Angeles	Palmdale	34 25	118 03	3,299
Magic Hill	B. L. Hutchings	do	Burbank	34 23	118 22	2,820
Holcomb Creek	Arrowhead Reservoir Co.	San Bernardino	San Bernardino	34 18	116 58	5,220
Upper Holcomb	do	do	do	34 18	116 50	7,200
Mount Sister Elsie	L. T. Rowley	Los Angeles	Monte Vista	34 17	118 14	5,021
Deep Creek	Arrowhead Reservoir Co.	San Bernardino	San Bernardino	34 17	117 05	5,200
Mount Lowe	Prof. Lewis Swift	Los Angeles	Echo Mountain.	34 15	118 07	3,200
Little Bear Valley	Arrowhead Reservoir Co.	San Bernardino	San Bernardino	34 15	117 10	5,150
Follows's camp	B. W. Follows	Los Angeles	Azusa	34 14	117 49	1,800
Colby's camp	D. W. Colby	do	Pasadena			3,875
Morse's house	Arrowhead Reservoir Co.	San Bernardino	San Bernardino	34 12	117 12	5,350
Squirrel Inn	do	do	do	34 12	117 12	5,300
Mill Creek	Redlands E. L. and P. Co.	do	Redlands			5,000
Do	do	do	do			2,915
Cuyamaca	San Diego Flume Co.	San Diego	San Diego	32 58	115 35	4,800
Descanso	E. W. Hubbard	do	Descanso	32 50	116 40	3,500
Sweetwater dam	G. N. Savage	do	National City	32 43	117 00	250
Millwood	Sanger Lumber Co.	Fresno	Sanger			

Precipitation at rainfall stations in southern California, 1899.

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Sisson	5.55	1.08	2.98	0.23	1.32	0.89	0.00	.....	0.00	4.01	10.83	5.67	32.51
Redbluff	9.29	0.01	6.22	0.72	.....	0.94	0.00	0.02	0.00	3.02	4.08	3.80	28.10
Sonora	6.99	0.42	14.03	1.08	2.18	2.17	0.00	0.08	0.00	6.90	7.02	5.38	46.25
Second Garrotte	6.75	1.00	14.00	0.50	1.00	0.00	0.00	0.00	0.00	6.75	6.75	6.00	43.75
Crockers	8.32	1.00	15.89	1.50	0.15	1.65	0.00	0.00	0.00	8.10	7.45	11.38	55.54
Yosemite[a]	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Milo	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Taylor's ranch	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.78	0.66	.....
Kernville	1.95	0.19	1.89	0.28	0.25	0.45	0.00	0.00	0.00	0.78	0.85	0.73	7.37
Mount Breckenridge	1.67	0.94	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Tejon ranch	1.30	2.10	4.03	0.82	0.00	0.00	0.00	0.00	0.00	1.31	1.82	1.67	13.05
Fort Tejon	2.57	0.50	2.99	0.55	0.25	0.78	0.00	0.00	0.05	1.10	1.71	1.40	11.90
Bear Valley	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3.21	1.94	.....
Frazier mine	.....	.....	.....	.....	.....	0.60	0.00	.....	.....	.....	.....	.....	.....
La Liebre	1.79	0.04	2.26	0.09	0.04	0.27	0.00	0.00	0.05	1.47	0.90	0.46	7.37
Smith's ranch	8.2	0.00	1.45	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.65	0.35	4.22
Sneddens	2.65	0.00	1.50	0.50	0.00	0.00	0.00	0.00	0.00	1.50	0.47	0.27	6.89
Mutah flat	2.25	0.00	2.50	0.50	0.00	0.00	0.00	0.00	0.00	2.00	1.30	2.25	10.80
Palmdale headworks	1.00	0.31	0.97	0.00	0.00	0.00	0.00	0.00	0.00	1.28	0.27	0.32	4.15
Magic Hill	1.60	0.15	2.07	0.14	1.55	0.05	0.00	0.00	0.07	2.25	1.07	1.20	10.15
Holcomb Creek	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Upper Holcomb	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Mount Sister Elsie	2.95	0.12	3.37	0.58	0.08	0.78	0.00	0.00	0.35	2.10	1.34	0.41	12.08
Deep Creek	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Mount Lowe	3.29	0.00	3.40	0.20	1.90	0.40	0.00	0.00	0.00	3.00	2.85	.....	15.04
Glenn ranch	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.96	1.00	.....
Little Bear Valley	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Follows's camp	3.59	0.84	2.49	0.12	0.00	0.91	0.00	0.00	0.12	3.03	1.64	0.44	13.18
Colby's camp	2.90	0.25	2.73	0.17	0.60	0.79	0.00	0.00	0.00	3.66	1.25	1.26	13.61
Morse's house	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Squirrel Inn	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Mill Creek	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Mill Creek	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Cuyamaca	7.02	1.53	7.23	0.98	.....	2.96	0.04	T.	0.00	4.51	3.45	2.49	30.21
Descanso	3.49	1.69	2.73	0.25	1.45	.....	0.15	0.38	.....	.....	0.25	1.06	11.45
Sweetwater dam	2.40	0.70	0.89	0.23	0.11	0.58	0.00	0.00	0.00	0.41	1.66	0.77	7.75
Millwood	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

[a] No record.

MISCELLANEOUS DISCHARGE MEASUREMENTS IN NEBRASKA.

The following miscellaneous measurements of discharge were made in Nebraska during the year 1899:

Miscellaneous measurements of discharge in Nebraska in 1899.

Stream.	Where measured.	Date.	Discharge.	Hydrographer.
			Sec.-feet.	
Ash Creek	At mouth	May 15	0.76	C. B. Channel.
Baker Creek	North line sec. 19, T. 31 N., R. 13 W.	June 19	.35	Do.
Beaver Creek	At Hyer's, sec. 20, T. 34 N., R. 46 W.	May 22	8.97	Do.
Birdwood Creek	1 mile above mouth	May 25	183.47	H. H. Pickens.
Blue Creek	South line sec. 18, T. 17 N., R. 42 W.	May 22	90.12	Do.
Boardman Creek	At Buckley's, sec. 13, T. 30 N., R. 31 W.	June 8	16.4	C. B. Channel.
Boggy Creek	West line sec. 31, T. 33 N., R. 54 W.	May 24	.05	A. B. McCoskey.
Bone Creek	At Stringer's, sec. 16, T. 31 N., R. 21 W.	June 17	12.46	C. B. Channel.
Calamus River	Burwell	May 17	372.	Glenn E. Smith.
Do	Sec. 8, T. 24 N., R. 19 W	Sept. 20	152.5	C. B. Channel.
Cedar Creek	Above Bruce's mill, sec. 33, T. 24 N., R. 25 W.	July 9	7.41	Do.

Miscellaneous measurements of discharge in Nebraska in 1899—Continued.

Stream.	Where measured.	Date.	Discharge.	Hydrographer.
			Sec.-feet.	
Cedar irrigation ditch.	Ericson	May 17	19.6	Glenn E. Smith.
Cedar River	Ericson, above dam	....do	107.4	Do.
Do	Ericson, below dam	....do	113.	Do.
Chadron Creek	North line sec. 36, T. 33 N., R. 49 W.	....do	8.71	C. B. Channel.
Do	Above waterworks dam, sec. 18, T. 32 N., R. 48 W.	....do	2.24	Do.
Do	Below waterworks dam	....do	2.15	Do.
Clear Creek	700 yards below Barber & Marsh head gate, sec. 32, T. 16 N., R. 41 W.	May 19	7.84	H. H. Pickens.
Do	At Schlademan's, sec. 5, T. 14 N., R. 34 W.	Dec. 16	3.4	C. B. Channel.
Cottonwood Creek.	Sec. 21, T. 35 N., R. 22 W	June 12	1.2	H. H. Pickens.
Crooked Creek	At Mutz, sec. 19, T. 34 N., R. 19 W.	June 13	1.23	C. B. Channel.
Culbertson canal	Below head gate	May 29	43.94	H. H. Pickens.
Dead Horse Creek	North line sec. 31, T. 33 N., R. 49 W.	May 17	3.46	C. B. Channel.
Do	At Slattery's ditch, sec. 32, T. 33 N., R. 49 W.	....do	3.98	Do.
Dismal River	Dunning	Apr. 21	334.48	Do.
Dry Cedar Creek	At mouth, near Ericson	May 17	5.	Glenn E. Smith.
East Ash Creek	Head of Tomlin's ditch, sec. 30, T. 32 N., R. 50 W.	May 15	3.35	C. B. Channel.
Do	Head of Shelton ditch, sec. 33, T. 32 N., R. 50 W.	Aug. 18	.33	A. B. McCoskey.
East Middle Creek.	Sec. 32, T. 33 N., R. 23 W	June 10	.27	C. B. Channel.
Elkhorn River	O'Neill	July 8	145.77	Do.
Frenchman River.	At Palisade, below canal	May 29	53.39	H. H. Pickens.
Do	West line sec. 5, T. 5 N., R. 38 W.	June 3	29.54	Do.
Do	Maranville's, sec. 12, T. 6 N., R. 41 W.	July 8	19.33	E. D. Johnson.
Do	Below head gate of Inman's ditch	July 9	16.62	Do.
Do	At head gate of Wirsig ditch, sec. 24, T. 6 N., R. 40 W.	July 10	20.98	Do.
Do	At Palisade	Sept. 16	50.61	A. B. McCoskey.
Do	At Culbertson	....do	29.92	Do.
Do	At Wauneta	Sept. 19	62.91	Do.
Goose Creek	Sec. 10, T. 22 N., R. 27 W.	Apr. 27	30.27	C. B. Channel.
Holt Creek	Head of Webster & Carnahan ditch, sec. 19, T. 35 N., R. 20 W.	June 12	3.58	Do.
Horse Creek	Nebraska-Wyoming line	June 16	11.1	A. B. McCoskey.
Horsehead Creek	Sec. 16, T. 33 N., R. 24 W	June 9	1.15	C. B. Channel.
Indiana Creek	North line sec. 33, T. 32 N., R. 50 W.	Aug. 18	.5	A. B. McCoskey.
Keya Paha River	Sec. 24, T. 35 N., R. 20 W	June 13	38.99	C. B. Channel.
Little Cottonwood Creek.	West line T. 31 N., R. 51 W	May 15	.29	Do.
Do	Below mouth of Spring Creek	May 16	.35	Do.
Lodgepole Creek	3 miles east of Sidney	May 15	10.95	H. H. Pickens.
Do	4 miles west of Kimball	Aug. 9	7.43	E. D. Johnson.
Do	1 mile west of Kimball	....do	2.41	Do.
Do	½ mile east of Kimball	Aug. 11	2.04	Do.
Do	¼ mile above head G. Kinney ditch. sec. 33, T. 15 N., R. 56 W.	Aug. 10	6.52	Do.
Do	Above Young's head gate	....do	15.57	Do.
Long Pine Creek	Below Miller's mills, sec. 5, T. 31 N., R. 20 W.	June 15	90.67	C. B. Channel.
Middle Loup River.	Arcadia	Apr. 18	809.66	A. B. McCoskey.
Do	Dunning	Apr. 21	408.23	Do.
Do	Seneca	May 2	225.34	C. B. Channel.
Mill race	At Ericson	May 17	6.5	Glenn E. Smith.
Minichaduza River.	Valentine	Jan. 27	26.2	Do.
Do	....do	Feb. 21	45.	Do.
Do	....do	Mar. 15	25.7	Do.
Do	....do	Apr. 26	32.6	Do.
Do	....do	May 11	35.	Do.
Do	....do	May 26	64.7	Do.
Do	....do	June 26	23.	Do.
Do	....do	Aug. 13	19.	Do.
Do	....do	Sept. 13	23.5	Do.
Do	....do	Sept. 26	26.5	Do.
Hat Creek	Above Coffee's ditch, sec. 26, T. 33 N., R. 55 W.	May 24	3.6	A. B. McCoskey.
Newman Creek	Head Newman ditch, sec. 17, T. 33 N., R. 24 W.	June 9	.73	C. B. Channel.
Niobrara River	Bourette, sec. 32, T. 30 N., R. 56 W.	May 27	13.65	Do.
Do	Mouth of Whistle Creek	May 28	33.04	Do.

Miscellaneous measurements of discharge in Nebraska in 1899—Continued.

Stream.	Where measured.	Date.	Discharge.	Hydrographer.
			Sec.-feet.	
Niobrara River..	Marland	May 29	36.16	C. B. Channel.
Do	Head Hatch & Cross ditch, sec. 25, T. 29 N., R. 50 W.	....do...	47.94	Do.
Do	Cook ranch, sec. 6, T. 28 N., R. 55 W.	Aug. 3	13.87	A. B. McCoskey.
Do	Curtis ranch, sec. 1, T. 28 N., R. 56 W.	Aug. 16	10.15	Do.
Do	5 miles south of Valentine	Mar. 15	650.	Glenn E. Smith.
North Fork Elkhorn River.	Norfolk	Feb. 20	119.	Do.
Do	....do	Apr. 27	122.	Do.
Do	....do	May 25	414.	Do.
Do	....do	Aug. 17	81.3	Do.
Do	....do	Sept. 25	85.2	Do.
North Loup River	Brownlee	May 1	359.79	C. B. Channel.
Do	Burwell	May 16	984.	Glenn E. Smith.
Do	Brewster	Sept. 21	361.92	C. B. Channel.
Do	Brownlee	Sept. 23	195.84	Do.
North Platte River.	Llewellen bridge	May 22	15,901.88	H. H. Pickens.
Do	Gering	June 14	16,104.8	A. B. McCoskey.
Oak Creek	3 miles northwest of Lincoln	May 10	27.46	Do.
Do	Below Elche's, 3 miles northwest of Lincoln, after heavy rains.	July 3	708.25	Do.
Do	Dannebrog	May 19	5.	Glenn E. Smith.
Platte River	Central City (estimated)	Sept. 8	20.	Do.
Plum Creek	Sec. 35, T. 33 N., R. 23 W.	June 10	81.07	C. B. Channel.
Republican River.	Above mouth of Frenchman River.	May 29	Dry.	H. H. Pickens.
Do	Orleans, below mouth of Sappa Creek.	Sept. 6	.25	Glenn E. Smith.
Do	Oxford	....do...	Dry.	Do.
Do	Above Frenchman River	Sept. 19	Dry.	A. B. McCoskey.
Do	McCook	....do...	12.27	Do.
Do	Head of irrigation and water-power canal, sec. 15, T. 3 N., R. 31 W.	....do...	17.5	E. D. Johnson.
Sandy Creek	Sec. 3, T. 31 N., R. 15 W	June 17	8.28	C. B. Channel.
Shobe Branch	Lambs, sec. 32, T. 33 N., R. 11 W.	June 20	1.66	Do.
South Platte River.	North Platte	Apr. 19	883.	Glenn E. Smith.
Do	....do	May 6	866.	Do.
Do	....do	May 22	88.	Do.
Do	....do	June 6	Dry.	Do.
Do	....do	June 19	Dry.	Do.
Do	Sutherland	May 23	50.	H. H. Pickens.
Sowbelly Creek	North line sec. 19, T. 32 N., R. 55 W.	Aug. 1	1.37	A. B. McCoskey.
Spring Creek	Head Townsend ditch, sec. 35, T. 34 N., R. 19 W.	May 16	5.18	C. B. Channel.
Do	Head Opperman's ditch, sec. 5, T. 31 N., R. 20 W.	June 15	.31	Do.
Squaw Creek	Duncan, sec. 28, T. 31 N., R. 51 W.	May 11	1.21	Do.
Do	Stetsons, sec. 18, T. 31 N., R. 51 W	....do...	.33	Do.
Do	Head proposed Daniel & Stetson ditch.	....do...	.79	Do.
Do	Head Cooper ditch, sec. 36, T. 32 N., R. 52 W.	May 12	.72	Do.
Stinkingwater River.	Above Palisade	May 29	21.60	H. H. Pickens.
Thompson Creek	Sec. 4, T. 2 N., R. 13 W	Sept. 8	3.45	E. D. Johnson.
Trunk Butte Creek.	North line sec. 36, T. 33 N., R. 50 W.	May 17	1.45	C. B. Channel.
Do	Sec. 3, T. 52 N., R. 50 W.	Aug. 18	.34	A. B. McCoskey.
Turkey Creek	Sec. 30, T. 4 N., R. 21 W	Sept. 6	2.26	E. D. Johnson.
Warbonnet Creek	Brewster's ranch, sec. 21, T. 33 N., R. 56 W.	May 25	2.50	A. B. McCoskey.
West Ash Creek	At Woodwards, sec. 25, T. 32 N., R. 51 W.	May 15	.19	C. B. Channel.
West Middle Creek.	Sec. 32, T. 33 N., R. 23 W.	June 2	1.48	Do.
White River	Whitney	May 15	10.37	E. D. Johnson.
Do	Below Crawford	May 17	18.68	A. B. McCoskey.
Do	Force's ranch	May 19	4.41	Do.
Do	Head Crawford ditch	...do....	16.70	Do.
Do	Below Crawford	...do....	18.05	Do.
Do	....do	May 22	45.89	Do.
Do	Andrews siding	May 26	4.93	C. B. Channel.
Do	Below Crawford	Aug. 19	16.20	A. B. McCoskey.
White Clay Creek	Sec. 13, T. 32 N., R. 51 W.	May 11	.72	C. B. Channel.
Do	Brooks, sec. 2, T. 33 N., R. 45 W	May 20	5.27	Do.
Wooden Spring Branch.	Sec. 25, T. 35 N., R. 29 W.	June 13	2.14	Do.

RATING TABLES.

The following pages contain the rating tables prepared for various river stations described in Papers Nos. 35 to 39, inclusive. These show the relation which has been found to exist during the year 1899 between the height of water on the gage at each locality and the discharge in cubic feet per second. These tables have been prepared from the measurements made during 1899 or previous years, and are used in computing the daily flow, the results of which are to be given in the Twenty-first Annual Report, Part IV. Taking, for example, the first table, No. 62, Delaware River at Lambertville, New Jersey, the number 62 refers to the page upon which the river station is described. At the end of the description are given the results of discharge measurements made during 1899. From these and earlier data the relation of gage height to discharge has been deduced and is given in the following tables. On page 63 is given the daily height in feet. On March 1 this was 6.80. In the following table the flow equivalent to this height is shown to be 33,710 second-feet. In the same manner the flow corresponding to each gage height in the table has been obtained and the averages computed, for use, as above noted, in the annual report relating to the year 1899.

Rating tables for stations in New Jersey, Pennsylvania, Maryland, and West Virginia.

[Number in box head refers to page in Water-Supply and Irrigation Paper No. 35.]

Gage height in feet.	Discharge in second-feet.											
	62. Delaware River at Lambertville, New Jersey.	75. North Branch of Susquehanna River at Wilkesbarre, Pennsylvania.	77. North Branch of Susquehanna River at Danville, Pennsylvania.	78. West Branch of Susquehanna River at Allenwood, Pennsylvania.	79. Juniata River at Newport, Pennsylvania.	80. Susquehanna River at Harrisburg, Pennsylvania.	81. Octoraro Creek at Rowlandsville, Maryland.	88. Patapsco River at Woodstock, Maryland.	86. Antietam Creek at Sharpsburg, Maryland.	90. Shenandoah River at Millville, West Virginia.	91. Potomac River at Point of Rocks, Maryland.	93. Monocacy River at Frederick, Maryland.
0.0	.....	.....	.....	.....	.....	3,000	.....	.....	.....	.....	750	.....
0.2	.....	.....	.....	.....	.....	3,650	.....	.....	.....	.....	1,000	.....
0.4	.....	.....	.....	.....	.....	4,350	.....	.....	.....	.....	1,400	.....
0.6	.....	.....	.....	.....	.....	5,050	.....	.....	.....	740	1,800	.....
0.8	.....	.....	.....	.....	.....	5,900	.....	.....	.....	940	2,400	.....
1.0	.....	.....	.....	.....	.....	7,000	.....	.....	.....	1,140	3,100	.....
1.2	.....	.....	.....	.....	.....	8,200	.....	.....	38	1,370	3,900	.....
1.4	.....	.....	.....	.....	.....	9,450	.....	.....	60	1,650	4,700	.....
1.6	.....	.....	.....	750	.....	10,750	.....	.....	105	1,950	5,500	.....
1.8	.....	.....	970	1,050	.....	12,300	.....	.....	171	2,260	6,400	.....
2.0	.....	.....	1,350	1,350	.....	13,900	.....	.....	233	2,600	7,300	.....
2.2	.....	1,000	1,750	1,700	.....	15,500	.....	.....	294	2,960	8,300	.....
2.4	1,750	1,200	2,250	2,150	.....	17,300	.....	.....	356	3,340	9,300	.....
2.6	2,100	1,400	2,750	2,650	.....	19,300	.....	.....	417	3,740	10,300	.....
2.8	2,600	1,600	3,300	3,250	600	21,300	.....	.....	479	4,160	11,300	.....
3.0	3,300	1,860	3,900	4,000	1,000	23,400	.....	50	544	4,600	12,350	.....
3.2	4,100	2,120	4,550	5,200	1,400	25,625	110	83	644	5,060	13,450	.....
3.4	5,050	2,400	5,250	7,500	1,820	27,925	155	122	766	5,540	14,550	.....
3.6	6,100	2,700	6,000	10,750	2,270	30,300	225	173	887	6,050	15,650	45
3.8	7,250	3,000	6,800	14,000	2,750	32,800	305	235	1,000	6,600	16,800	90
4.0	8,550	3,300	7,600	17,250	3,250	35,400	385	310	1,114	7,190	18,000	150
4.2	10,000	3,600	8,500	20,500	3,750	38,100	465	400	1,227	7,790	19,200	210
4.4	11,650	3,940	9,400	23,750	4,300	41,100	545	520	1,340	8,410	20,400	270
4.6	13,350	4,340	10,400	27,000	4,900	44,590	635	670	1,454	9,040	21,600	340
4.8	15,050	4,760	11,400	30,250	5,500	48,170	725	835	1,567	9,680	22,800	420
5.0	16,750	5,200	12,500	33,500	6,200	51,750	815	1,000	1,680	10,320	24,000	500
5.2	18,500	5,700	13,700	36,750	6,900	55,330	910	1,200	1,794	10,960	25,200	600
5.4	20,300	6,250	14,900	40,000	7,700	58,910	1,010	1,400	1,908	11,600	26,400	700
5.6	22,150	6,850	16,100	43,250	8,500	62,490	1,110	1,600	2,022	12,240	27,600	800
5.8	24,050	7,560	17,390	46,500	9,350	66,070	1,210	1,800	2,136	12,880	28,800	900
6.0	25,950	8,340	18,800	49,750	10,250	69,650	1,314	2,000	2,250	13,520	30,100	1,020
6.2	27,850	9,240	20,240	53,000	11,150	73,230	1,418	2,205	2,364	14,160	31,400	1,192
6.4	29,750	10,260	21,680	56,250	12,060	76,810	1,522	2,410	2,478	14,800	32,700	1,364
6.6	31,700	11,360	23,120	59,500	13,000	80,390	1,628	2,615	2,592	15,440	34,100	1,536
6.8	33,710	12,480	24,560	62,750	14,000	83,970	1,736	2,820	2,706	16,080	35,500	1,708
7.0	35,750	13,600	26,000	66,000	15,000	87,550	1,844	3,025	2,820	16,720	36,950	1,880
7.5	40,900	16,400	29,600	74,125	17,500	96,500	2,114	3,538	3,105	.....	40,800	2,310
8.0	46,050	19,200	33,200	82,250	20,000	105,450	.....	4,050	3,390	.....	44,900	2,740
8.5	51,200	22,000	36,800	.....	22,500	114,400	.....	4,562	.....	.....	49,300	3,170
9.0	56,350	24,800	40,400	.....	25,000	123,350	.....	.....	.....	.....	53,850	3,600
9.5	61,500	27,600	44,000	.....	27,500	132,300	.....	.....	.....	.....	58,400	4,030
10.0	.....	30,400	47,600	.....	30,000	141,250	.....	.....	.....	.....	62,950	4,460
10.5	.....	33,200	51,200	.....	32,500	150,200	.....	.....	.....	.....	67,500	4,890
11.0	.....	36,000	54,800	.....	35,000	159,150	.....	.....	.....	.....	72,050	5,320
11.5	.....	38,800	58,400	.....	.....	168,100	.....	.....	.....	.....	76,600	5,750
12.0	.....	41,600	62,000	.....	.....	177,050	.....	.....	.....	.....	81,150	6,180
12.5	.....	44,400	.....	.....	.....	186,000	.....	.....	.....	.....	85,700	6,610
13.0	.....	47,200	.....	.....	.....	194,950	.....	.....	.....	.....	90,250	7,040
13.5	.....	50,000	.....	.....	.....	203,900	.....	.....	.....	.....	94,800	7,470
14.0	.....	52,800	.....	.....	.....	212,850	.....	.....	.....	.....	99,350	7,900
14.5	.....	.....	.....	.....	.....	221,800	.....	.....	.....	.....	103,900	8,330
15.0	.....	.....	.....	.....	.....	230,750	.....	.....	.....	.....	108,450	8,760
15.5	.....	.....	.....	.....	.....	239,700	.....	.....	.....	.....	113,000	9,190
16.0	.....	.....	.....	.....	.....	248,650	.....	.....	.....	.....	117,550	9,620
16.5	.....	.....	.....	.....	.....	257,600	.....	.....	.....	.....	122,100	10,050
17.0	.....	.....	.....	.....	.....	266,550	.....	.....	.....	.....	126,650	10,480

Rating tables for stations in Virginia and North Carolina.

[Number in box head refers to page in Water-Supply and Irrigation Paper No. 35 or No. 36.]

Gage height in feet.	Discharge in second-feet.											
	95. North (of James) River at Glasgow, Virginia.	97. James River at Buchanan, Virginia.	107. Roanoke River at Roanoke, Virginia.	109. Roanoke River at Neal, North Carolina.	110. Tar River at Tarboro, North Carolina.	111. Neuse River at Selma, North Carolina.	112. Haw River at Moncure, North Carolina.	113. Deep River at Moncure, North Carolina.	115. Cape Fear River at Fayetteville, North Carolina.	116. Yadkin River at Salisbury, North Carolina.	118. Yadkin River at Norwood, North Carolina.	120. Catawba River at Catawba, North Carolina.
0.2	.....	.....	.....	.....	.....	145	.....	.....	.....	.....	.....	.....
0.4	.....	.....	.....	.....	370	176	.....	.....	.....	.....	.....	.....
0.6	155	.....	70	.....	410	215	.....	210	.....	.....	.....	.....
0.8	180	.....	110	.....	453	255	.....	230	.....	.....	.....	.....
1.0	200	.....	170	2,270	500	295	290	250	489	.....	1,500	.....
1.2	220	.....	240	2,410	555	335	350	290	550	.....	2,080	.....
1.4	290	.....	325	2,550	615	377	415	330	612	.....	2,670	.....
1.6	410	.....	420	2,690	675	419	500	380	678	1,600	3,270	850
1.8	560	370	540	2,830	735	462	600	440	744	2,000	3,900	1,050
2.0	730	530	670	2,970	800	506	700	500	810	2,500	4,600	1,270
2.2	920	690	820	3,110	875	551	820	560	876	3,100	5,400	1,540
2.4	1,120	850	1,010	3,250	963	600	950	630	946	3,700	6,240	1,840
2.6	1,340	1,010	1,240	3,390	1,031	650	1,090	715	1,022	4,300	7,080	2,200
2.8	1,570	1,180	1,540	3,530	1,110	700	1,230	805	1,103	5,000	7,920	2,600
3.0	1,810	1,380	1,920	3,670	1,200	750	1,370	900	1,187	5,700	8,760	3,000
3.2	2,070	1,590	2,325	3,810	1,300	800	1,530	1,070	1,273	6,500	9,630	3,450
3.4	2,330	1,810	2,735	3,960	1,400	860	1,690	1,240	1,367	7,300	10,600	3,900
3.6	2,610	2,070	3,145	4,090	1,500	920	1,850	1,410	1,467	8,100	11,780	4,375
3.8	2,890	2,340	3,555	4,230	1,600	980	2,010	1,580	1,567	8,900	12,980	4,875
4.0	3,190	2,620	3,965	4,370	1,700	1,040	2,170	1,750	1,674	9,700	14,180	5,400
4.2	3,490	2,920	4,375	4,510	1,810	1,100	2,340	1,940	1,782	10,500	15,380	5,940
4.4	3,790	3,220	4,785	4,650	1,920	1,168	2,510	2,130	1,890	11,300	16,580	6,495
4.6	4,090	3,520	5,195	4,790	2,030	1,236	2,680	2,320	1,994	12,100	17,820	7,065
4.8	4,390	3,830	5,605	4,930	2,140	1,305	2,850	2,510	2,102	12,900	19,060	7,640
5.0	4,690	4,150	6,015	5,070	2,250	1,385	3,020	2,700	2,210	13,700	20,300	8,225
5.5	5,490	5,050	7,040	5,420	2,550	1,585	3,445	3,175	2,470	15,700	23,510	9,700
6.0	6,400	6,030	8,065	5,770	2,865	1,805	3,870	3,650	2,740	17,900	26,800	11,175
6.5	7,420	7,080	9,090	6,120	3,200	2,030	4,310	4,125	3,010	20,200	30,300	12,650
7.0	8,540	8,130	10,115	6,525	3,550	2,255	4,760	4,600	3,280	22,700	33,800	14,125
7.5	9,910	9,300	11,140	6,970	3,910	2,500	5,210	5,100	3,550	25,650	37,800	15,600
8.0	11,400	10,600	12,165	7,420	4,285	2,750	5,660	5,600	3,822	29,100	41,800	17,075
8.5	12,900	11,930	.....	7,870	4,685	3,000	6,110	6,100	4,102	33,000	46,300	18,550
9.0	14,430	13,310	.....	8,345	5,085	3,250	6,600	6,600	4,382	37,000	51,000	20,025
9.5	15,930	14,740	.....	8,840	5,500	3,500	7,100	7,100	4,672	41,000	56,250	21,500
10.0	17,430	16,240	.....	9,340	5,915	3,750	7,600	7,600	4,955	45,000	61,500	22,975
10.5	18,930	17,820	.....	9,840	6,330	4,000	8,100	8,100	5,245	49,000	66,750	24,450
11.0	20,430	19,430	.....	10,340	6,750	4,280	8,600	8,600	5,535	53,000	72,000	25,925
11.5	21,930	21,170	.....	10,840	7,175	4,610	9,100	9,100	5,833	57,000	.....	27,400
12.0	23,430	22,920	.....	11,340	7,600	4,960	9,600	9,600	6,133	61,000	.....	28,875
12.5	24,930	24,680	.....	11,840	8,025	5,320	10,100	10,100	6,443	65,000	.....	30,350
13.0	26,430	26,630	.....	12,340	8,470	5,695	10,600	10,600	6,733	69,000	.....	31,825
13.5	.....	28,700	.....	12,890	8,920	6,070	11,100	11,100	7,033	73,000	.....	33,300
14.0	.....	30,850	.....	13,440	9,370	6,450	11,600	11,600	7,333	77,000	.....	34,775
14.5	.....	33,000	.....	14,040	9,820	6,850	12,100	12,100	7,633	81,000	.....	36,250
15.0	.....	35,150	.....	14,640	10,270	7,250	12,600	12,600	7,933	85,000	.....	37,725
16.0	.....	39,450	.....	15,940	11,170	8,050	13,600	13,680	8,541	93,000	.....	40,675
17.0	.....	43,750	.....	17,240	12,070	8,850	14,600	14,780	9,161	101,000	.....	43,650
18.0	.....	48,050	.....	18,600	12,970	9,650	15,600	15,880	9,781	109,000	.....	46,650
19.0	.....	52,350	.....	20,400	13,870	10,450	16,600	16,980	10,401	117,000	.....	49,650
20.0	.....	.....	.....	22,400	14,850	11,250	17,600	18,080	11,569	.....	.....	52,650
25.0	.....	.....	.....	39,700	19,850	.....	22,600	23,580	18,364	.....	.....	.....
30.0	.....	.....	.....	.....	.....	.....	.....	.....	25,159	.....	.....	.....
35.0	.....	.....	.....	.....	.....	.....	.....	.....	33,600	.....	.....	.....
40.0	.....	.....	.....	.....	.....	.....	.....	.....	44,000	.....	.....	.....
45.0	.....	.....	.....	.....	.....	.....	.....	.....	54,500	.....	.....	.....
50.0	.....	.....	.....	.....	.....	.....	.....	.....	65,000	.....	.....	.....

Rating tables for stations in South Carolina and Georgia.

[Number in box head refers to page in Water-Supply and Irrigation Paper No. 36.]

Gage height in feet.	Discharge in second-feet.											
	121. Catawba River at Rockhill, South Carolina.	123. Broad River at Gaffney, South Carolina.	125. Broad River at Alston, South Carolina.	126. Saluda River at Waterloo, South Carolina.	127. Tugaloo River at Madison, Carolina.	129. Savannah River at Calhoun Falls, South Carolina.	130. Savannah River at Augusta, Georgia.	131. Broad River at Carlton, Georgia.	133. Oconee River at Dublin, Georgia.	134. Yellow River at Almon, Georgia.	136. Ocmulgee River at Macon, Georgia.	139. Chattahoochee River at Oakdale, Georgia, lower gage.
									a			
—0.2	.....	.....	.....	.....	.....	.....	.....	.....	1,300	.....	.....	.....
0.0	.....	.....	.....	.....	.....	.....	.....	.....	1,425	.....	.....	400
0.2	.....	.....	.....	.....	.....	.....	.....	.....	1,552	.....	580	480
0.4	.....	.....	.....	.....	.....	.....	.....	.....	1,681	.....	620	560
0.6	.....	.....	.....	.....	.....	.....	.....	.....	1,812	.....	690	680
0.8	.....	.....	.....	.....	563	.....	.....	.....	1,945	.....	770	780
1.0	.....	.....	.....	.....	665	.....	.....	.....	2,080	120	850	900
1.2	.....	600	.....	.....	767	.....	.....	.....	2,218	147	940	1,020
1.4	1,560	780	.....	.....	869	.....	.....	.....	2,358	175	1,040	1,150
1.6	1,750	1,050	.....	.....	971	.....	.....	380	2,500	212	1,140	1,280
1.8	2,030	1,350	.....	.....	1,073	.....	.....	450	2,644	255	1,250	1,420
2.0	2,390	1,650	1,520	300	1,175	.....	.....	540	2,790	300	1,360	1,560
2.2	2,830	1,960	1,800	320	1,277	1,990	.....	660	2,988	345	1,480	1,700
2.4	3,390	2,300	2,160	350	1,379	2,190	.....	800	3,089	390	1,600	1,850
2.6	4,060	2,660	2,520	400	1,481	2,490	.....	940	3,243	435	1,720	2,000
2.8	4,880	3,020	2,900	465	1,583	2,870	.....	1,080	3,400	480	1,840	2,150
3.0	5,750	3,400	3,300	550	1,685	3,420	.....	1,220	3,560	525	1,960	2,300
3.2	6,632	3,820	3,700	650	1,787	4,160	.....	1,370	3,720	570	2,080	2,470
3.4	7,516	4,260	4,100	750	1,889	5,096	.....	1,520	3,890	615	2,200	2,650
3.6	8,400	4,720	4,500	850	1,991	5,924	.....	1,680	4,070	660	2,320	2,850
3.8	9,284	5,200	4,900	950	2,098	6,812	.....	1,840	4,280	705	2,440	3,050
4.0	10,168	5,680	5,300	1,050	2,195	7,700	2,350	2,000	4,460	750	2,560	3,250
4.2	11,052	6,160	5,800	1,156	2,310	8,588	2,470	2,180	4,672	795	2,680	3,450
4.4	11,936	6,640	6,300	1,262	2,435	9,476	2,695	2,360	4,888	840	2,800	3,650
4.6	12,820	7,120	6,800	1,368	2,570	10,364	2,725	2,550	5,108	885	2,920	3,900
4.8	13,704	7,600	7,360	1,474	2,710	11,252	2,860	2,750	5,332	930	3,040	4,150
5.0	14,588	8,080	7,920	1,580	2,860	12,140	3,000	2,950	5,560	975	3,160	4,400
5.2	15,472	8,560	8,500	1,686	3,020	13,028	3,160	3,160	5,788	1,020	3,280	4,660
5.4	16,356	9,040	9,100	1,805	3,180	13,916	3,340	3,390	6,016	1,065	3,400	4,920
5.6	17,240	9,520	9,700	1,935	3,340	14,804	3,540	3,640	6,244	1,110	3,520	5,180
5.8	18,124	10,000	10,300	2,065	3,500	15,692	3,760	3,900	6,472	1,155	3,640	5,440
6.0	19,008	10,480	11,000	2,200	3,660	16,580	4,000	4,160	6,700	.....	3,760	5,700
6.5	21,218	11,680	12,750	2,550	4,060	18,800	4,620	4,825	7,270	.....	4,060	6,370
7.0	23,428	12,880	14,700	2,900	4,460	21,020	5,300	5,500	7,840	.....	4,360	7,000
7.5	25,638	14,080	16,950	3,275	4,860	23,240	6,050	6,175	8,410	.....	4,660	7,650
8.0	27,848	15,280	19,200	3,670	5,260	25,460	6,800	6,850	8,980	.....	5,010	8,300
8.5	30,058	16,480	21,450	4,075	5,660	27,680	7,600	7,525	9,550	.....	5,410	8,950
9.0	32,268	17,680	23,700	4,500	6,060	29,900	8,400	8,200	10,120	.....	5,810	9,600
9.5	34,478	18,880	25,950	4,950	6,460	32,120	9,250	8,875	10,690	.....	6,250	10,250
10.0	36,688	20,080	28,200	5,400	6,860	34,340	10,100	9,550	11,260	.....	6,820	10,900
11.0	40,108	22,480	32,700	6,350	7,660	38,780	11,900	10,900	12,400	.....	8,120	12,200
12.0	45,528	24,880	37,200	7,350	8,460	43,220	13,800	12,250	13,540	.....	10,010	13,500
13.0	49,948	.....	41,700	8,400	9,260	47,660	15,800	13,600	14,680	.....	12,900	14,800
14.0	54,368	.....	46,200	9,500	10,060	52,100	17,900	14,950	15,820	.....	16,000	16,100
15.0	58,788	.....	50,700	10,650	10,860	.....	20,100	16,300	16,960	.....	19,200	17,400
16.0	62,208	.....	55,200	11,850	11,660	.....	22,400	17,650	18,100	.....	22,400	18,700
18.0	72,048	.....	64,200	14,350	.....	.....	27,300	.....	20,380	.....	.....	21,300
20.0	.....	.....	.....	.....	.....	.....	33,300	.....	22,660	.....	.....	23,900
22.0	.....	.....	.....	.....	.....	.....	41,000	.....	24,940	.....	.....	26,500
24.0	.....	.....	.....	.....	.....	.....	52,000	.....	27,220	.....	.....	29,100
26.0	.....	.....	.....	.....	.....	.....	68,800	.....	.....	.....	.....	31,700

a Continued: Gage height —1.20, discharge 890; gage height —1.00, discharge 950; gage height —0.8, discharge 1,015; gage height —0.6, discharge 1,095; gage height —0.4, discharge 1,185.

Rating tables for stations in Georgia, Alabama, Maryland, and West Virginia.

[Number in box head refers to page in Water-Supply and Irrigation Paper No. 36.]

Gage height in feet.	Discharge in second-feet.											
	139. Chattahoochee River at Oakdale, Georgia, upper gage.	142. Chattahoochee River at West Point, Georgia.	143. Etowah River at Canton, Georgia.	144. Coosawattee River at Carters, Georgia.	146. Oostanaula River at Resaca, Georgia.	148. Coosa River at Rome, Georgia.	149. Coosa River at Riverside, Alabama.	152. Tallapoosa River at Milstead, Alabama.	156. Black Warrior River at Tuscaloosa, Alabama.	159. Youghiogheny River at Friendsville, Maryland.	163. Greenbrier River at Alderson, West Virginia.	164. New River at Fayette, West Virginia.
—0.4	.....	.....	275	.....	.....	.....	.....	.....	205	.....	.....	.....
—0.2	.....	.....	385	.....	.....	.....	.....	.....	240	.....	.....	.....
0.0	.....	.....	515	.....	.....	.....	.....	.....	280	.....	.....	1,400
0.2	910	.....	665	.....	.....	.....	.....	.....	340	.....	.....	1,550
0.4	1,000	.....	820	.....	.....	1,550	.....	.....	400	.....	.....	1,700
0.6	1,100	.....	988	230	.....	1,710	.....	.....	460	.....	.....	1,850
0.8	1,220	.....	1,154	280	.....	1,870	.....	430	580	.....	.....	2,000
1.0	1,350	935	1,320	345	460	2,080	2,460	672	600	.....	.....	2,150
1.2	1,490	1,000	1,486	420	500	2,218	2,760	918	670	.....	60	2,310
1.4	1,630	1,180	1,652	495	550	2,406	3,100	1,164	750	.....	120	2,480
1.6	1,780	1,380	1,818	580	600	2,620	3,500	1,410	880	.....	220	2,660
1.8	1,940	1,600	1,984	675	650	2,860	3,940	1,656	910	.....	350	2,850
2.0	2,100	1,840	2,150	770	705	3,100	4,400	1,902	1,000	.....	505	3,050
2.2	2,270	2,100	2,316	872	770	3,420	4,900	2,148	1,090	.....	685	3,270
2.4	2,450	2,380	2,482	977	840	3,740	5,430	2,394	1,180	.....	920	3,490
2.6	2,630	2,680	2,648	1,086	920	4,060	5,970	2,630	1,270	.....	1,205	3,720
2.8	2,810	3,000	2,814	1,200	1,000	4,380	6,530	2,876	1,370	.....	1,535	3,960
3.0	3,000	3,340	2,980	1,318	1,080	4,700	7,100	3,132	1,470	.....	1,900	4,200
3.2	3,200	3,700	3,146	1,440	1,175	5,100	7,700	3,378	1,570	.....	2,330	4,480
3.4	3,405	4,080	3,312	1,566	1,275	5,500	8,330	3,624	1,670	.....	2,770	4,760
3.6	3,615	4,480	3,478	1,698	1,380	5,900	8,970	3,870	1,780	.....	3,240	5,060
3.8	3,825	4,920	3,644	1,834	1,490	6,300	9,620	4,116	1,890	.....	3,720	5,380
4.0	4,035	5,370	3,810	1,970	1,610	6,700	10,300	4,362	2,000	260	4,200	5,700
4.2	4,250	5,880	3,976	2,106	1,780	7,102	11,040	4,608	2,111	295	4,680	6,060
4.4	4,470	6,400	4,142	2,242	1,860	7,504	11,780	4,854	2,222	350	5,160	6,442
4.6	4,700	6,940	4,308	2,378	2,005	7,906	12,520	5,100	2,333	425	5,660	6,890
4.8	4,930	7,490	4,474	2,514	2,160	8,308	13,260	5,346	2,444	520	6,180	7,338
5.0	5,160	8,040	4,640	2,650	2,330	8,710	14,000	5,592	2,555	640	6,700	7,786
5.5	5,850	9,420	5,055	2,990	2,780	9,715	15,850	6,207	2,832	1,050	8,000	8,906
6.0	6,600	10,800	5,470	3,330	3,230	10,720	17,700	6,822	3,110	1,600	9,500	10,026
6.5	7,350	12,180	5,885	3,670	3,690	11,725	19,550	7,437	3,370	2,170	11,000	11,146
7.0	8,100	13,560	6,300	4,010	4,150	12,730	21,400	8,052	3,665	2,740	12,500	12,290
7.5	8,850	14,950	6,715	4,350	4,610	13,735	23,250	8,667	3,925	3,310	14,000	13,490
8.0	9,600	16,400	7,130	4,690	5,070	14,740	25,100	9,282	4,220	3,880	15,600	14,820
8.5	10,350	17,850	7,545	5,080	5,530	15,745	26,950	9,897	4,480	4,450	17,300	16,170
9.0	11,100	19,300	7,960	5,370	5,990	16,750	28,800	10,512	4,775	5,020	19,000	17,600
9.5	11,850	20,750	8,375	5,710	6,450	17,755	30,650	11,127	5,035	5,590	20,700	19,190
10.0	12,600	22,200	8,790	6,050	6,910	18,760	32,500	11,742	5,330	.....	22,500	20,920
11.0	14,100	25,100	9,620	6,780	7,830	20,770	36,200	12,972	5,885	.....	26,500	24,480
12.0	.....	28,800	10,450	7,410	8,750	22,780	39,900	14,202	6,440	.....	31,200	28,050
13.0	.....	33,410	11,280	8,090	9,670	24,790	43,600	15,432	6,996	.....	36,200	31,620
14.0	.....	38,030	12,110	8,770	10,590	26,800	47,300	16,662	7,550	.....	41,200	35,200
15.0	.....	42,630	12,940	9,450	11,510	28,810	51,000	17,892	8,105	.....	46,200	38,770
16.0	.....	.....	13,770	10,130	12,430	30,820	54,700	19,122	8,660	.....	.....	42,340
17.0	.....	.....	14,600	10,810	13,350	32,830	58,400	20,352	9,215	.....	.....	45,910
18.0	.....	.....	15,430	11,490	14,270	34,840	62,100	21,582	9,770	.....	.....	49,480
19.0	.....	.....	.....	12,170	15,190	36,850	.....	22,812	10,325	.....	.....	53,050
20.0	.....	.....	.....	.....	16,110	38,860	.....	24,042	10,880	.....	.....	56,620
25.0	.....	.....	.....	.....	20,710	48,910	.....	30,192	16,000	.....	.....	74,470
30.0	.....	.....	.....	.....	.....	58,960	.....	36,342	24,600	.....	.....	92,320
35.0	.....	.....	.....	.....	.....	.....	.....	42,492	35,000	.....	.....	110,170
40.0	.....	.....	.....	.....	.....	.....	.....	.....	49,000	.....	.....	.....
45.0	.....	.....	.....	.....	.....	.....	.....	.....	65,250	.....	.....	.....
50.0	.....	.....	.....	.....	.....	.....	.....	.....	84,000	.....	.....	.....
55.0	.....	.....	.....	.....	.....	.....	.....	.....	102,750	.....	.....	.....
60.0	.....	.....	.....	.....	.....	.....	.....	.....	121,500	.....	.....	.....

Rating tables for stations in North Carolina, Georgia, Tennessee, Ohio, and Montana.

[Number in box head refers to page in Water-Supply and Irrigation Paper No. 36 or No. 37].

Gage height in feet.	Discharge in second-feet.												
	165. French Broad River at Asheville, North Carolina.	167. Tuckasegee River at Bryson, North Carolina.	168. Little Tennessee River at Judson, North Carolina.	169. Hiwassee River at Murphy, North Carolina.	171. Toccoa River at Blueridge, Georgia.	174. Tennessee River at Chattanooga, Tennessee.	175. Olentangy River at Columbus, Ohio.	176. Scioto River at Columbus, Ohio.	195. West Gallatin River at Salesville, Montana.	196. Middle Creek at Bozeman, Montana.	205. Madison River at Redbluff, Montana.	208. Missouri River at Townsend, Montana.
								a				*b*
−0.2	.....	.....	.....	.....	.....	.....	.....	.....	.....	380	.....	.....
0.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	410	.....	.....
0.2	.....	.....	.....	.....	.....	.....	.....	.....	.....	440	.....	.....
0.4	.....	.....	.....	.....	.....	.....	.....	.....	.....	470	.....	2,000
0.6	.....	.....	.....	.....	.....	.....	.....	.....	.....	500	.....	2,400
0.8	.....	.....	.....	.....	.....	6,600	.....	.....	.....	530	.....	2,800
1.0	.....	300	.....	.....	.....	7,300	30	15	.....	560	850	3,250
1.2	.....	460	.....	.....	.....	8,040	90	50	.....	590	1,500	3,750
1.4	.....	620	.....	.....	.....	8,820	160	100	.....	620	2,150	4,250
1.6	.....	824	.....	.....	.....	9,620	250	150	.....	650	2,800	4,800
1.8	.....	1,072	.....	.....	.....	10,430	360	200	.....	680	3,450	5,400
2.0	820	1,320	225	.....	255	11,250	490	250	.....	710	4,100	6,000
2.2	990	1,652	300	.....	305	12,080	640	300	.....	740	4,750	6,600
2.4	1,180	1,984	445	.....	370	12,930	810	350	.....	770	5,400	7,250
2.6	1,400	2,330	610	.....	475	13,800	1,000	400	.....	800	6,050	7,960
2.8	1,620	2,720	805	.....	610	14,680	1,210	460	650	.....	6,700	8,650
3.0	1,860	3,150	1,060	.....	760	15,600	1,430	540	690	.....	7,350	9,400
3.2	2,120	3,620	1,360	.....	912	16,550	1,660	640	740	.....	8,000	10,200
3.4	2,380	4,160	1,670	.....	1,064	17,550	1,900	760	810	.....	8,650	11,000
3.6	2,660	4,800	1,990	.....	1,216	18,550	2,140	900	900	.....	9,300	11,900
3.8	2,950	5,530	2,320	.....	1,368	19,600	2,390	1,050	1,010	.....	9,950	12,900
4.0	3,290	6,320	2,650	.....	1,520	20,800	2,640	1,210	1,160	.....	.....	14,000
4.2	3,710	7,150	3,020	.....	1,672	22,040	2,900	1,390	1,350	.....	.....	15,200
4.4	4,210	8,000	3,390	.....	1,824	23,280	3,170	1,570	1,580	.....	.....	16,400
4.6	4,760	8,850	3,770	225	1,976	24,520	3,450	1,750	1,870	.....	.....	17,600
4.8	5,350	9,700	4,160	280	2,128	25,760	3,745	1,940	2,210	.....	.....	19,000
5.0	6,020	10,550	4,550	340	2,280	27,000	4,060	2,140	2,600	.....	.....	20,400
5.5	7,920	12,675	5,600	620	2,660	30,100	4,930	2,670	3,600	.....	.....	25,000
6.0	9,820	14,800	6,750	1,280	3,040	33,200	5,830	3,230	4,600	.....	.....	30,650
6.5	11,720	16,925	7,975	2,130	3,420	36,300	.....	3,870	5,600	.....	.....	36,900
7.0	13,620	19,050	9,300	2,980	3,800	39,400	.....	4,610	6,600	.....	.....	43,150
7.5	15,520	21,300	10,720	3,830	4,180	42,500	.....	5,475	7,600	.....	.....	49,400
8.0	17,420	23,550	12,275	4,680	4,560	45,600	.....	6,400	8,600	.....	.....	55,650
8.5	19,320	26,050	14,087	5,530	4,940	48,700	.....	7,325	9,600	.....	.....	.....
9.0	21,220	28,550	16,100	6,380	5,320	51,800	.....	8,250	.....	.....	.....	.....
9.5	23,120	31,050	18,275	7,230	.....	54,900	.....	9,175	.....	.....	.....	.....
10.0	25,020	33,550	20,600	8,080	.....	58,000	.....	10,100	.....	.....	.....	.....
11.0	28,820	38,550	25,600	9,780	.....	64,200	.....	11,950	.....	.....	.....	.....
12.0	.....	.....	30,600	11,480	.....	70,400	.....	13,800	.....	.....	.....	.....
13.0	.....	.....	35,600	13,180	.....	76,600	.....	.....	.....	.....	.....	.....
14.0	.....	.....	.....	14,880	.....	82,800	.....	.....	.....	.....	.....	.....
15.0	.....	.....	.....	16,580	.....	89,000	.....	.....	.....	.....	.....	.....
16.0	.....	.....	.....	18,280	.....	95,200	.....	.....	.....	.....	.....	.....
17.0	.....	.....	.....	19,980	.....	101,400	.....	.....	.....	.....	.....	.....
18.0	.....	.....	.....	21,680	.....	107,600	.....	.....	.....	.....	.....	.....
19.0	.....	.....	.....	.....	.....	113,800	.....	.....	.....	.....	.....	.....
20.0	.....	.....	.....	.....	.....	120,000	.....	.....	.....	.....	.....	.....
22.0	.....	.....	.....	.....	.....	132,400	.....	.....	.....	.....	.....	.....
24.0	.....	.....	.....	.....	.....	144,800	.....	.....	.....	.....	.....	.....
26.0	.....	.....	.....	.....	.....	157,200	.....	.....	.....	.....	.....	.....
28.0	.....	.....	.....	.....	.....	169,600	.....	.....	.....	.....	.....	.....
30.0	.....	.....	.....	.....	.....	182,000	.....	.....	.....	.....	.....	.....
32.0	.....	.....	.....	.....	.....	194,400	.....	.....	.....	.....	.....	.....
34.0	.....	.....	.....	.....	.....	206,800	.....	.....	.....	.....	.....	.....
36.0	.....	.....	.....	.....	.....	219,200	.....	.....	.....	.....	.....	.....
40.0	.....	.....	.....	.....	.....	244,000	.....	.....	.....	.....	.....	.....

a Gage heights in the table should be increased by 8 feet, in order to correspond with gage heights on the rod at Columbus.

b Gage heights in the table should be increased by 88 feet, in order to correspond with gage heights on the rod at Townsend.

Rating tables for stations in Montana, Wyoming, Nebraska, and Colorado.

[Number in box head refers to page in Water-Supply and Irrigation Paper No. 37.]

Gage height in feet.	Discharge in second-feet.											
	209. Milk River at Havre, Montana, Jan. 1 to Sept. 17.	209. Milk River at Havre, Montana, Sept. 18 to Dec. 31.	212. Clear Creek at Buffalo, Wyoming.	214. Laramie River at Woods Landing, Wyoming.	216. Laramie River at Uva, Wyoming.	217. North Platte River at Orin Junction, Wyoming.	218. North Platte River at Gering, Nebraska.a	219. North Platte River at Camp Clarke, Nebraska.	220. North Platte River at North Platte, Nebraska. Jan. 1 to Sept. 20.	220. North Platte River at North Platte, Nebraska. Oct. 4 to Dec. 31.	222. Goose Creek at Lake Cheesman, Colorado.	223. South Fork of South Platte River at Lake Cheesman, Colorado.
0.2	90	.....	9	.....	.....	.....	.....	.....	.....	.....	.....	.....
0.3	98	.....	17	40	.....	.....	.....	.....	.....	.....	.....	.....
0.4	110	.....	25	45	.....	.....	.....	.....	.....	.....	.....	.....
0.5	124	.....	33	50	5	.....	.....	.....	.....	.....	.....	.....
0.6	140	.....	46	60	10	0	.....	.....	.....	.....	.....	.....
0.7	160	.....	64	70	15	40	.....	.....	.....	.....	7	.....
0.8	183	.....	82	85	21	100	.....	.....	.....	.....	9	24
0.9	208	.....	104	100	30	170	507	.....	.....	.....	12	36
1.0	235	80	134	125	40	240	893	.....	.....	.....	24	49
1.1	265	84	169	155	50	310	1,316	.....	.....	.....	38	65
1.2	295	90	209	200	62	380	1,777	.....	.....	.....	53	86
1.3	330	98	246	245	80	450	2,275	.....	.....	.....	68	115
1.4	365	110	286	290	100	525	2,811	.....	.....	.....	83	145
1.5	400	124	323	350	120	600	3,385	.....	889	.....	98	175
1.6	440	140	365	410	140	680	3,997	.....	1,149	622	.....	205
1.7	480	160	406	475	160	760	4,647	.....	1,495	713	.....	234
1.8	525	183	447	550	185	850	5,335	.....	1,845	984	.....	264
1.9	570	208	504	630	210	940	6,061	.....	2,215	1,270	.....	294
2.0	620	235	558	720	240	1,080	6,824	600	2,619	1,557	.....	323
2.2	725	295	657	960	300	1,230	8,465	1,049	3,427	2,275	.....	383
2.4	845	365	752	1,240	370	1,480	10,257	1,646	4,235	3,138	.....	442
2.6	980	.....	856	1,530	450	1,760	12,200	2,391	5,197	4,001	.....	501
2.8	1,135	.....	.....	1,820	540	2,070	14,295	3,285	6,317	.....	.....	561
3.0	1,305	.....	.....	2,110	660	2,400	16,541	4,327	7,437	.....	.....	621
3.2	1,480	.....	.....	2,400	810	2,780	18,939	5,517	8,557	.....	.....	680
3.4	1,680	.....	.....	2,690	1,000	3,240	21,489	6,855	9,851	.....	.....	740
3.6	1,880	.....	.....	2,980	1,200	3,790	24,189	8,342	11,330	.....	.....	800
3.8	2,080	.....	.....	3,270	1,405	4,555	.....	9,977	12,962	.....	.....	860
4.0	2,280	.....	.....	3,560	1,611	5,445	.....	11,760	14,606	.....	.....	.....
4.2	2,480	.....	.....	3,850	1,817	6,335	.....	13,691	16,257	.....	.....	.....
4.4	2,680	.....	.....	4,140	2,023	7,225	.....	15,771	17,894	.....	.....	.....
4.6	2,880	.....	.....	4,430	2,229	8,115	.....	18,000	.....	.....	.....	.....
4.8	.....	.....	.....	.....	2,435	9,005	.....	20,375	.....	.....	.....	.....
5.0	.....	.....	.....	.....	2,641	9,895	.....	22,900	.....	.....	.....	.....
5.2	.....	.....	.....	.....	2,847	10,785	.....	25,573	.....	.....	.....	.....
5.4	.....	.....	.....	.....	3,053	11,760	.....	28,394	.....	.....	.....	.....
5.6	.....	.....	.....	.....	3,259	12,835	.....	.....	.....	.....	.....	.....
5.8	.....	.....	.....	.....	3,465	14,020	.....	.....	.....	.....	.....	.....
6.0	.....	.....	.....	.....	3,611	15,230	.....	.....	.....	.....	.....	.....
6.2	.....	.....	.....	.....	.....	16,480	.....	.....	.....	.....	.....	.....
6.4	.....	.....	.....	.....	.....	17,770	.....	.....	.....	.....	.....	.....
6.6	.....	.....	.....	.....	.....	19,100	.....	.....	.....	.....	.....	.....
6.8	.....	.....	.....	.....	.....	20,470	.....	.....	.....	.....	.....	.....
7.0	.....	.....	.....	.....	.....	21,880	.....	.....	.....	.....	.....	.....
7.2	.....	.....	.....	.....	.....	23,330	.....	.....	.....	.....	.....	.....

a These rating tables were applied by the indirect method described on pages 323 et seq. of the Nineteenth Annual Report, Part IV.

Rating tables for stations in Colorado and Nebraska.

[Number in box head refers to page in Water-Supply and Irrigation Paper No. 37.]

Gage height in feet.	Discharge in second-feet.											
	224. South Platte River at Platte Canyon, Colorado.	225. South Platte River at Denver, Colorado.	226. South Platte River at Orchard, Colorado, Jan. 1 to Mar. 18.	226. South Platte River at Orchard, Colorado, Mar. 19 to Dec. 31.	227. Bear Creek at Morrison, Colorado.	228. Clear Creek at Forkscreek, Colorado.	229. South Boulder Creek at Marshall, Colorado.	231. Boulder Creek at Boulder, Colorado.	232. St. Vrain Creek at Lyons, Colorado.	233. Big Thompson Creek at Arkins, Colorado.	237. North Loup River at St. Paul, Nebraska. *b*	238. Middle Loup River at St. Paul, Nebraska. *b*
	a											
0.0	125							0				
0.1	146				0			7				
0.2	168				1			14		4		
0.3	190				2			21		8		
0.4	213				2			28		19		
0.5	236				3			36		35		
0.6	260				4			45		60		
0.7	284				5		7	55		88		
0.8	308				7		13	67		116		
0.9	333				8		20	80		146		
1.0	359				9		29	95		176		625
1.1	386				10		39	113		206		655
1.2	413				11		49	133		236		685
1.3	441				12		60	156		267		715
1.4	470				13	32	72	182		299		745
1.5	500				15	44	86	211		331	465	780
1.6	531				16	58	102	242		365	590	820
1.7	563				17	75	121	276		399	600	865
1.8	596				19	98	143	321		433	680	925
1.9	631			19	21	112	167	366	13	469	750	990
2.0	669		0	40	22	133	198	412	25	510	835	1,065
2.2	754		40	115	25	179	248	504	51	619	1,000	1,250
2.4	850		113	206	27	235	308	596	80	769	1,175	1,480
2.6	954		195	340	31	299	375	688	113	1,008	1,360	1,740
2.8	1,066		288	614	34	367	452	780	155	1,251	1,560	2,050
3.0	1,185		408	936	37	441	536		204	1,499	1,760	2,390
3.2	1,305		598	1,258	41	522			268	1,747	1,960	
3.4	1,425		968	1,580	46	614			353		2,175	
3.6	1,545		1,342	1,902	54	719			477		2,400	
3.8	1,665		1,716	2,224	64	832			601		2,625	
4.0	1,785		2,090	2,546	80	946			729		2,900	
4.2	1,905		2,464	2,868	99	1,060			857			
4.4	2,025		2,838	3,190	119	1,174			985			
4.6	2,145		3,214	3,512	141	1,288			1,113			
4.8		52	3,590	3,834	166	1,402						
5.0		81	3,966	4,156	195							
5.2		121			225							
5.4		172			257							
5.6		232			290							
5.8		309			325							
6.0		422										
6.2		588										
6.4		755										
6.6		922										
6.8		1,088										
7.0		1,255										
7.2		1,422										

a Continued: Gage height −0.1, discharge 104; gage height −0.2, discharge 87; gage height −0.3, discharge 75; gage height −0.4, discharge 64; gage height −0.5, discharge 55; gage height −0.6, discharge 48; gage height −0.7, discharge 41; gage height −0.8, discharge 35; gage height −0.9, discharge 30; gage height −1.0, discharge 26; gage height −1.1, discharge 22; gage height −1.2, discharge 18.

b These rating tables were applied by the indirect method described on pages 223 et seq. of the Nineteenth Annual Report, Part IV.

Rating tables for stations in Nebraska, Kansas, and Colorado.

[Number in box head refers to page in Water-Supply and Irrigation Paper No 37.]

Gage height in feet.	Discharge in second-feet.											
	240. Loup River at Columbus, Nebraska.a	242. Platte River at Columbus, Nebraska.a	243. Elkhorn River at Norfolk, Nebraska.a	244. Elkhorn River at Arlington, Nebraska.a	245. Republican River at Superior, Nebraska.	248. Republican River at Junction, Kansas.	249. Solomon River at Niles, Kansas.	250. Saline River at Salina, Kansas.	251. Smoky Hill River at Ellsworth, Kansas.	252. Blue River at Manhattan, Kansas.	253. Kansas River at Lecompton, Kansas, July 9 to Dec. 31.b	256. Lake Creek at Twin Lakes, Colorado.
0.2	.....	.....	.....	.....	90	.....	.....	.....	.....	.....	.....	.....
0.3	.....	.....	.....	.....	140	.....	.....	.....	.....	.....	.....	.....
0.4	.....	.....	.....	.....	200	.....	.....	.....	.....	.....	.....	.....
0.5	.....	.....	115	308	270	.....	.....	.....	.....	.....	.....	.....
0.6	.....	.....	140	340	350	.....	.....	.....	.....	.....	.....	.....
0.7	.....	.....	166	377	445	.....	.....	.....	.....	.....	.....	.....
0.8	.....	.....	194	415	560	.....	.....	.....	.....	.....	.....	.....
0.9	.....	.....	224	452	700	.....	.....	.....	.....	.....	.....	.....
1.0	.....	.....	256	490	860	.....	.....	.....	10	.....	.....	.....
1.2	.....	.....	323	564	1,200	.....	.....	.....	28	.....	.....	.....
1.4	.....	.....	396	639	1,580	.....	.....	.....	56	.....	.....	.....
1.6	.....	.....	477	714	.....	.....	.....	.....	94	.....	.....	.....
1.8	.....	.....	562	789	.....	.....	.....	.....	135	.....	.....	.....
2.0	.....	.....	660	863	.....	.....	.....	.....	180	.....	1,850	.....
2.2	.....	.....	820	988	.....	.....	.....	.....	230	.....	2,070	.....
2.4	.....	.....	1,010	1,013	.....	.....	.....	.....	280	.....	2,320	.....
2.6	.....	1,078	.....	1,088	.....	115	.....	.....	335	.....	2,580	411
2.8	.....	2,324	.....	1,162	.....	205	.....	.....	390	.....	2,860	496
3.0	.....	3,100	.....	1,240	.....	295	.....	40	450	150	3,150	588
3.2	.....	4,000	.....	1,339	.....	395	.....	60	520	200	3,460	696
3.4	.....	5,000	.....	1,462	.....	500	.....	70	610	270	3,780	834
3.6	.....	6,050	.....	1,610	.....	615	.....	80	710	340	4,120	1,006
3.8	.....	7,400	.....	1,781	.....	735	.....	95	830	420	4,480	1,208
4.0	898	9,200	.....	1,977	.....	870	30	110	960	500	4,850	.....
4.2	1,241	11,300	.....	2,197	.....	1,020	45	125	1,100	590	5,240	.....
4.4	1,620	13,450	.....	2,441	.....	1,180	62	140	1,250	680	5,640	.....
4.6	2,040	16,400	.....	.....	.....	1,360	81	156	1,400	770	6,060	.....
4.8	2,500	19,700	.....	.....	.....	1,570	100	173	1,550	860	6,500	.....
5.0	2,995	23,700	.....	.....	.....	1,780	120	190	1,700	960	6,950	.....
5.2	3,530	28,400	.....	.....	.....	2,030	142	205	1,850	1,060	7,420	.....
5.4	4,101	.....	.....	.....	.....	2,320	165	220	2,000	1,160	7,930	.....
5.6	4,712	.....	.....	.....	.....	2,610	190	236	2,150	1,270	8,470	.....
5.8	5,358	.....	.....	.....	.....	2,910	215	254	2,300	1,380	9,030	.....
6.0	6,040	.....	.....	.....	.....	3,230	242	270	2,460	1,500	9,600	.....
6.5	7,910	.....	.....	.....	.....	4,080	319	315	2,865	1,825	11,200	.....
7.0	.....	.....	.....	.....	.....	.....	400	360	3,290	2,175	13,000	.....
7.5	.....	.....	.....	.....	.....	.....	490	405	3,715	2,560	14,900	.....
8.0	.....	.....	.....	.....	.....	.....	600	457	4,160	2,970	16,800	.....
8.5	.....	.....	.....	.....	.....	.....	713	514	4,650	3,400	.....	.....
9.0	.....	.....	.....	.....	.....	.....	834	565	5,150	3,850	.....	.....
9.5	.....	.....	.....	.....	.....	.....	959	627	5,660	4,315	.....	.....
10.0	.....	.....	.....	.....	.....	.....	1,087	680	6,230	4,800	.....	.....
10.5	.....	.....	.....	.....	.....	.....	1,217	737	6,885	5,325	.....	.....
11.0	.....	.....	.....	.....	.....	.....	1,351	800	7,460	5,870	.....	.....
11.5	.....	.....	.....	.....	.....	.....	1,487	862	8,170	6,425	.....	.....
12.0	.....	.....	.....	.....	.....	.....	1,625	927	8,950	7,000	.....	.....
12.5	.....	.....	.....	.....	.....	.....	1,770	997	9,810	7,605	.....	.....
13.0	.....	.....	.....	.....	.....	.....	1,920	1,060	10,986	8,240	.....	.....
13.5	.....	.....	.....	.....	.....	.....	2,070	.....	.....	8,970	.....	.....
14.0	.....	.....	.....	.....	.....	.....	2,220	.....	.....	9,860	.....	.....
14.5	.....	.....	.....	.....	.....	.....	2,380	.....	.....	10,910	.....	.....
15.0	.....	.....	.....	.....	.....	.....	2,540	.....	.....	12,080	.....	.....
16.0	.....	.....	.....	.....	.....	.....	2,870	.....	.....	14,280	.....	.....
17.0	.....	.....	.....	.....	.....	.....	3,220	.....	.....	16,580	.....	.....
18.0	.....	.....	.....	.....	.....	.....	3,590	.....	.....	18,780	.....	.....
20.0	.....	.....	.....	.....	.....	.....	4,450	.....	.....	23,280	.....	.....

Discharges represent flow passing over dam only. Discharge of millrace should be added to give total flow of stream.

a These rating tables were applied by the indirect method described on pages 323 et seq. of the Nineteenth Annual Report, Part IV.

b Rating table from April 16 to July 8, 1899, as follows: Gage height 3.00, discharge 2,150; gage height 3.50, discharge 2,800; gage height 4.00, discharge 3,600; gage height 5.00, discharge 5,800; gage height 6.00, discharge 9,200; gage height 7.00, discharge 13,000; gage height 10.00, discharge 24,800.

Rating tables for stations in Colorado and Kansas.

[Number in box head refers to page in Water-Supply and Irrigation Paper No. 37.]

Gage height in feet.	Discharge in second-feet.											
	258. Arkansas River at Salida, Colorado.	268. Arkansas River at Canyon, Colorado.	259. Arkansas River at Pueblo, Colorado, Jan. 1 to June 21.	259. Arkansas River at Pueblo, Colorado, June 22 to Dec. 31.	260. Arkansas River at Nepesta, Colorado.	261. Arkansas River at Rockyford, Colorado.	263. Purgatory River at Trinidad, Colorado.	265. Arkansas River at Hutchinson, Kansas.	265. Verdigris River at Liberty, Kansas.	267. Neosho River at Iola, Kansas.	277. Rio Grande at Del Norte, Colorado.	279. Rio Grande at Centivero, Colorado.
−0.6	.....	.....	.....	150	.....	.....	.....	.....	.....	.....	.....	.....
−0.5	.....	.....	.....	180	.....	.....	.....	.....	.....	.....	.....	.....
−0.4	.....	.....	.....	213	.....	.....	.....	.....	.....	.....	.....	.....
−0.3	.....	.....	.....	250	.....	.....	.....	.....	.....	.....	.....	.....
−0.2	.....	.....	.....	295	.....	.....	.....	.....	.....	.....	.....	.....
−0.1	.....	.....	.....	348	.....	.....	.....	.....	.....	.....	.....	.....
0.0	.....	.....	136	409	.....	.....	.....	.....	.....	.....	.....	.....
0.1	.....	.....	178	478	.....	.....	.....	.....	.....	.....	.....	.....
0.2	.....	.....	232	555	.....	.....	.....	.....	.....	.....	.....	.....
0.3	.....	.....	300	640	.....	.....	.....	.....	.....	.....	.....	.....
0.4	240	.....	372	733	.....	.....	.....	.....	.....	.....	.....	.....
0.5	256	.....	448	834	.....	.....	.....	.....	.....	.....	.....	.....
0.6	274	.....	527	941	.....	75	.....	.....	.....	.....	.....	.....
0.7	294	.....	609	1,050	.....	95	.....	.....	.....	.....	.....	9
0.8	317	.....	695	1,162	.....	115	.....	.....	.....	.....	.....	12
0.9	342	.....	784	1,276	.....	140	.....	.....	.....	.....	.....	20
1.0	368	.....	876	1,391	.....	190	.....	.....	.....	.....	.....	31
1.1	396	.....	972	1,507	.....	270	.....	25	.....	.....	.....	46
1.2	426	.....	1,070	1,624	.....	370	.....	30	.....	.....	.....	65
1.3	458	.....	1,172	1,743	.....	470	.....	40	.....	.....	218	98
1.4	494	.....	1,278	1,864	.....	570	.....	52	.....	.....	280	129
1.5	537	.....	1,392	1,988	.....	670	.....	70	0	.....	342	170
1.6	594	.....	1,510	2,114	.....	770	.....	90	2	.....	405	212
1.7	670	.....	1,633	2,240	.....	870	.....	115	5	0	470	254
1.8	764	.....	1,760	2,366	.....	970	.....	145	9	1	537	297
1.9	859	.....	1,892	2,492	.....	1,070	.....	180	14	25	606	339
2.0	954	135	2,028	2,618	.....	1,170	.....	220	20	50	678	381
2.2	1,144	186	2,314	2,870	.....	1,370	.....	385	39	110	829	.....
2.4	1,334	242	2,617	3,122	.....	1,570	.....	570	68	180	988	.....
2.6	1,524	316	2,936	3,374	.....	1,770	.....	800	110	260	1,161	.....
2.8	1,714	408	3,26.	3,626	154	1,970	.....	1,040	171	350	1,350	.....
3.0	1,904	560	3,588	3,878	191	2,170	.....	1,300	256	450	1,565	.....
3.2	2,094	807	3,914	4,130	235	2,370	.....	1,585	351	565	1,809	.....
3.4	2,284	1,057	4,240	4,383	285	2,570	16	1,895	450	700	2,061	.....
3.6	2,474	1,307	4,565	4,637	346	2,770	52	2,210	553	865	2,315	.....
3.8	2,664	1,557	4,891	4,891	427	2,970	109	2,570	660	1,050	.....	.....
4.0	2,854	1,807	.....	.....	610	3,170	280	3,010	770	1,250	.....	.....
4.2	3,044	2,057	.....	.....	974	3,370	492	3,600	890	1,465	.....	.....
4.4	3,234	2,307	.....	.....	1,337	3,570	1,012	4,210	1,010	1,700	.....	.....
4.6	3,424	2,557	.....	.....	1,701	.....	1,552	4,950	1,136	1,960	.....	.....
4.8	3,614	2,807	.....	.....	2,064	.....	2,092	5,810	1,268	2,250	.....	.....
5.0	3,804	3,057	.....	.....	2,428	.....	2,632	.....	1,400	2,550	.....	.....
5.5	.....	3,682	.....	.....	3,337	.....	.....	.....	1,760	3,310	.....	.....
6.0	.....	4,307	.....	.....	4,246	.....	.....	.....	2,160	4,100	.....	.....
6.5	.....	.....	.....	.....	5,156	.....	.....	.....	2,570	4,900	.....	.....
7.0	.....	.....	.....	.....	6,064	.....	.....	.....	2,980	5,700	.....	.....
7.5	.....	.....	.....	.....	6,521	.....	.....	.....	3,390	6,500	.....	.....
8.0	.....	.....	.....	.....	.....	.....	.....	.....	3,800	7,325	.....	.....
8.5	.....	.....	.....	.....	.....	.....	.....	.....	4,210	8,137	.....	.....
9.0	.....	.....	.....	.....	.....	.....	.....	.....	4,620	8,960	.....	.....
9.5	.....	.....	.....	.....	.....	.....	.....	.....	5,030	9,762	.....	.....
10.0	.....	.....	.....	.....	.....	.....	.....	.....	5,440	10,575	.....	.....
12.0	.....	.....	.....	.....	.....	.....	.....	.....	7,080	13,850	.....	.....
14.0	.....	.....	.....	.....	.....	.....	.....	.....	8,720	17,150	.....	.....
16.0	.....	.....	.....	.....	.....	.....	.....	.....	10,360	20,450	.....	.....
18.0	.....	.....	.....	.....	.....	.....	.....	.....	12,150	23,750	.....	.....

Rating tables for stations in New Mexico, Wyoming, Utah, and Colorado.

[Number in box head refers to page in Water-Supply and Irrigation Paper No. 37 or No. 38.]

Gage height in feet.	Discharge in second-feet.											
	280. Rio Grande at Embudo, New Mexico.	281. Rio Grande at Rio Grande, New Mexico.	286. Green River at Greenriver, Wyoming.	287. Black Fork of Green River at Granger, Wyoming.	292. Green River at Blake, Utah.	294. Grand River at Grand Junction, Colorado, right channel.	294. Grand River at Grand Junction, Colorado, left channel.	296. Uncompahgre River at Fort Crawford, Colorado.	297. Gunnison River at Grand Junction, Colorado.	298. Dolores River at Dolores, Colorado.	306. San Miguel River at Fallcreek, Colorado.	307. San Juan River at Arboles, Colorado.
−0.1	.....	.....	.....	70	.....	.....	.....	.....	.....	.....	.....	.....
0.0	.....	.....	.....	80	.....	.....	0	.....	.....	.....	.....	.....
0.1	.....	.....	.....	90	.....	.....	15	.....	.....	.....	.....	.....
0.2	.....	.....	.....	100	.....	.....	33	.....	.....	.....	.....	.....
0.3	.....	.....	.....	120	.....	.....	50	.....	.....	.....	.....	.....
0.4	.....	.....	.....	150	.....	.....	70	.....	.....	.....	.....	.....
0.5	.....	.....	830	180	.....	.....	92	.....	.....	.....	.....	.....
0.6	.....	.....	910	210	.....	.....	113	.....	.....	.....	.....	.....
0.7	.....	.....	990	245	.....	.....	137	.....	.....	.....	.....	.....
0.8	.....	.....	1,070	280	.....	.....	162	.....	.....	.....	.....	.....
0.9	.....	.....	1,150	315	.....	.....	195	.....	.....	.....	.....	.....
1.0	.....	.....	1,240	350	1,000	.....	228	.....	.....	.....	.....	.....
1.2	.....	.....	1,430	420	1,080	.....	315	.....	.....	.....	.....	.....
1.4	.....	.....	1,640	510	1,160	.....	433	.....	788	.....	.....	.....
1.6	.....	.....	1,870	610	1,250	.....	583	.....	848	.....	.....	.....
1.8	.....	.....	2,120	720	1,400	.....	765	.....	908	.....	.....	.....
2.0	.....	.....	2,390	840	1,600	.....	978	.....	968	.....	.....	.....
2.2	.....	.....	2,700	970	2,020	.....	1,221	.....	1,061	.....	25	.....
2.4	.....	.....	3,080	1,130	2,440	.....	1,492	.....	1,356	20	64	.....
2.6	.....	.....	3,540	1,320	2,860	.....	1,791	.....	1,652	37	105	.....
2.8	.....	.....	4,080	1,530	3,280	.....	2,118	5	1,948	82	150	.....
3.0	.....	.....	4,710	1,780	3,700	.....	2,473	10	2,246	164	204	.....
3.2	.....	.....	5,480	2,060	4,120	.....	2,857	19	2,546	280	265	.....
3.4	.....	.....	6,340	2,340	4,540	1,650	3,267	33	2,847	412	340	.....
3.6	.....	100	7,263	2,620	4,960	1,740	3,701	59	3,162	555	449	.....
3.8	.....	120	8,189	2,900	5,380	1,860	4,156	102	3,512	700	682	.....
4.0	.....	150	9,115	3,180	5,800	1,990	4,631	150	3,902	847	934	.....
4.2	.....	190	10,041	3,460	6,220	2,180	5,126	206	4,332	1,001	.....	.....
4.4	.....	230	10,967	3,740	6,650	2,450	5,641	278	4,802	1,160	.....	.....
4.6	.....	280	11,893	4,020	7,350	2,770	6,176	389	5,312	1,327	.....	.....
4.8	.....	340	12,819	4,300	8,100	3,120	6,731	512	5,862	1,506	.....	.....
5.0	.....	420	13,745	4,580	9,000	3,480	7,306	636	6,452	.....	.....	.....
5.2	.....	510	14,671	4,860	10,200	3,860	7,898	760	7,082	.....	.....	.....
5.4	.....	610	15,597	5,140	11,800	4,260	8,501	884	7,736	.....	.....	.....
5.6	.....	740	16,523	5,420	13,700	4,680	9,109	1,008	8,430	.....	.....	96
5.8	.....	890	17,449	5,700	15,600	5,120	9,719	1,132	9,164	.....	.....	138
6.0	.....	1,090	18,375	5,960	17,500	5,590	10,329	.....	9,938	.....	.....	200
6.2	.....	1,330	19,301	6,240	19,400	6,080	10,939	.....	10,752	.....	.....	328
6.4	.....	1,590	20,227	6,520	21,300	6,590	11,549	.....	11,606	.....	.....	516
6.6	65	1,910	21,153	.....	23,200	7,130	.....	.....	12,500	.....	.....	737
6.8	115	2,250	.....	.....	25,100	7,690	.....	.....	13,434	.....	.....	1,011
7.0	185	2,670	.....	.....	27,000	8,270	.....	.....	14,380	.....	.....	1,286
7.5	375	3,770	.....	.....	31,750	9,860	.....	.....	16,750	.....	.....	1,976
8.0	610	4,910	.....	.....	36,500	11,610	.....	.....	.....	.....	.....	.....
8.5	890	6,100	.....	.....	41,250	13,530	.....	.....	.....	.....	.....	.....
9.0	1,250	7,300	.....	.....	46,000	15,610	.....	.....	.....	.....	.....	.....
9.5	1,625	8,500	.....	.....	50,750	17,900	.....	.....	.....	.....	.....	.....
10.0	.....	9,700	.....	.....	55,500	20,390	.....	.....	.....	.....	.....	.....
10.5	.....	.....	.....	.....	60,250	23,030	.....	.....	.....	.....	.....	.....
11.0	.....	.....	.....	.....	65,000	25,800	.....	.....	.....	.....	.....	.....
11.5	.....	.....	.....	.....	.....	28,600	.....	.....	.....	.....	.....	.....

Rating tables for stations in Colorado, Arizona, Nevada, and Idaho.

[Number in box head refers to page in Water-Supply and Irrigation Paper No. 38.]

Gage height in feet.	Discharge in second-feet.											
	308. Piedra River at Arboles, Colorado.	309. Los Pinos River at Ignacio, Colorado.	310. Animas River at Durango, Colorado.	311. Florida River at Durango, Colorado.	312. Mancos River at Mancos, Colorado.	313. Gila River at San Carlos, Arizona.	325. North Fork of Humboldt River at Peko, Nevada.	326. Humboldt River at Elko, Nevada.	328. South Fork of Humboldt River at Mason's ranch, Nevada.	329. Humboldt River at Golconda, Nevada.	330. Humboldt River at Oreana, Nevada.	332. Bear River at Battlecreek, Idaho, Aug. 4 to Dec. 31. *a*
0.4	.....	.....	.....	.....	.....	.....	.....	.....	7	.....	.....	.....
0.5	.....	.....	.....	.....	.....	.....	.....	.....	15	15	.....	.....
0.6	.....	.....	.....	4	.....	.....	.....	.....	24	17	.....	.....
0.7	.....	.....	.....	9	0	.....	.....	.....	35	20	.....	.....
0.8	.....	.....	.....	16	1	.....	.....	.....	47	24	47	.....
0.9	.....	.....	.....	24	3	.....	.....	.....	60	29	59	.....
1.0	.....	.....	.....	32	5	.....	.....	.....	74	35	72	.....
1.1	.....	.....	.....	40	8	.....	.....	.....	89	41	87	.....
1.2	.....	.....	.....	50	12	.....	.....	.....	105	47	104	.....
1.3	.....	.....	.....	62	19	.....	.....	.....	122	54	123	.....
1.4	.....	.....	.....	75	29	.....	0.2	.....	141	62	144	.....
1.5	.....	.....	.....	89	42	60	1.0	.....	161	70	167	.....
1.6	.....	.....	.....	105	60	80	2.5	.....	182	78	191	930
1.7	.....	.....	.....	121	81	110	5	1	204	87	217	980
1.8	.....	.....	.....	139	102	140	8	7	227	96	245	1,030
1.9	.....	.....	.....	158	123	170	11	14	251	105	275	1,085
2.0	.....	.....	.....	179	144	200	14	22	276	114	308	1,140
2.1	.....	.....	.....	200	165	230	18	32	301	124	343	1,200
2.2	.....	36	.....	223	186	260	23	43	327	134	381	1,260
2.3	.....	49	.....	.....	207	290	29	56	354	145	422	1,325
2.4	25	67	.....	.....	228	330	35	70	382	156	466	1,390
2.5	38	89	.....	.....	249	370	42	86	410	168	512	1,460
2.6	52	124	.....	.....	270	410	50	104	439	180	561	1,530
2.7	68	180	.....	.....	291	460	59	128	469	193	613	1,605
2.8	88	236	.....	.....	312	520	69	144	499	206	668	1,680
2.9	111	292	.....	.....	333	590	80	166	529	220	725	1,760
3.0	138	349	.....	.....	354	680	92	190	559	235	785	1,845
3.2	200	463	.....	.....	.....	960	122	240	619	266	914	2,030
3.4	277	577	.....	.....	.....	1,498	160	292	679	298	1,055	.....
3.6	365	691	.....	.....	.....	2,174	207	346	740	332	1,205	.....
3.8	467	805	.....	.....	.....	2,850	263	402	801	367	1,362	.....
4.0	583	919	.....	.....	.....	3,526	327	461	862	404	1,523	.....
4.2	704	1,033	.....	.....	.....	4,202	396	525	922	443	1,688	.....
4.4	835	1,147	.....	.....	.....	4,878	469	594	983	485	1,858	.....
4.6	974	1,261	.....	.....	.....	5,554	546	667	1,045	530	2,033	.....
4.8	1,112	1,375	.....	.....	.....	6,230	628	743	1,106	578	2,212	.....
5.0	1,251	.....	.....	.....	.....	6,906	715	822	1,168	629	2,395	.....
5.2	1,390	.....	.....	.....	.....	7,582	806	903	1,230	684	.....	.....
5.4	1,529	.....	.....	.....	.....	8,258	899	987	1,292	742	.....	.....
5.6	.....	.....	.....	.....	.....	8,934	996	1,073	1,354	803	.....	.....
5.8	.....	.....	.....	.....	.....	9,610	1,094	1,166	1,416	868	.....	.....
6.0	.....	.....	.....	.....	.....	10,286	1,192	1,257	1,478	937	.....	.....
6.2	.....	.....	.....	.....	.....	.....	1,290	1,352	.....	1,011	.....	.....
6.4	.....	.....	168	.....	.....	.....	1,388	1,449	.....	1,093	.....	.....
6.6	.....	.....	237	.....	.....	.....	1,486	1,550	.....	1,183	.....	.....
6.8	.....	.....	315	.....	.....	.....	1,584	1,655	.....	1,281	.....	.....
7.0	.....	.....	402	.....	.....	.....	1,682	1,763	.....	1,387	.....	.....
7.2	.....	.....	504	.....	.....	.....	.....	1,873	.....	1,501	.....	.....
7.4	.....	.....	624	.....	.....	.....	.....	1,986	.....	1,623	.....	.....
7.6	.....	.....	786	.....	.....	.....	.....	2,101	.....	1,753	.....	.....
7.8	.....	.....	970	.....	.....	.....	.....	2,218	.....	1,888	.....	.....
8.0	.....	.....	1,160	.....	.....	.....	.....	2,339	.....	2,026	.....	.....
8.4	.....	.....	1,550	.....	.....	.....	.....	.....	.....	2,302	.....	.....
8.8	.....	.....	1,947	.....	.....	.....	.....	.....	.....	.....	.....	.....
9.2	.....	.....	2,364	.....	.....	.....	.....	.....	.....	.....	.....	.....
9.6	.....	.....	2,800	.....	.....	.....	.....	.....	.....	.....	.....	.....

a Rating table applicable from Jan. 1 to June 29 is the same as for 1898.

Rating tables for stations in Utah and Idaho.

[Number in box head refers to page in Water-Supply and Irrigation Paper No. 38.]

Gage height in feet.	Discharge in second-feet.											
	334. Logan River at Logan, Utah.	335. Bear River at Collinston, Utah.	337. Weber River at Uinta, Utah.	338. Provo River at Provo, Utah, Jan. 1 to June 22.	338. Provo River at Provo, Utah, June 23 to Oct. 21.	350. Portneuf River at Pocatello, Idaho.	351. Snake River at Montgomery, Idaho.	353. Little Wood River at Toponis, Idaho.	354. Malade River at Toponis, Idaho.	355. Malade River at Bliss, Idaho.	356. Bruneau River at Grandview, Idaho.	356. Boise River at Boise, Idaho.
0.9	.....	.....	.....	.....	.....	.....	.....	0.1	.....	.....	.....	.....
1.0	.....	.....	.....	.....	.....	.....	.....	0.5	.....	.....	10	867
1.1	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	25	986
1.2	.....	790	.....	.....	.....	.....	.....	1	5	.....	45	1,105
1.3	.....	870	.....	.....	.....	.....	.....	2	6	.....	55	1,224
1.4	.....	950	.....	.....	.....	.....	.....	2	6	.....	65	1,343
1.5	.....	1,050	320	.....	.....	.....	.....	2	7	.....	80	1,462
1.6	.....	1,150	375	.....	.....	.....	.....	4	7	.....	100	1,581
1.7	.....	1,260	445	.....	.....	.....	.....	6	8	.....	120	1,700
1.8	.....	1,370	520	.....	.....	.....	.....	8	9	.....	140	1,819
1.9	.....	1,485	595	.....	.....	.....	.....	10	10	.....	170	1,938
2.0	.....	1,600	675	.....	.....	.....	4,400	12	12	.....	200	2,057
2.1	.....	1,720	766	.....	.....	.....	4,500	14	14	1,060	230	2,197
2.2	.....	1,840	857	.....	.....	.....	4,600	18	18	1,120	270	2,390
2.3	200	1,965	948	.....	.....	.....	4,700	22	30	1,200	310	2,585
2.4	210	2,090	1,039	.....	.....	.....	4,800	26	45	1,300	360	2,780
2.5	230	2,215	1,130	.....	.....	.....	4,900	30	65	1,410	420	2,975
2.6	255	2,340	1,221	.....	.....	.....	5,000	34	85	1,540	485	3,170
2.7	280	2,465	1,312	.....	.....	.....	5,150	38	105	1,680	555	3,365
2.8	310	2,590	1,408	.....	.....	.....	5,300	43	130	1,825	630	3,560
2.9	345	2,715	1,494	.....	.....	.....	5,450	49	155	1,975	705	3,755
3.0	380	2,840	1,585	.....	.....	.....	5,600	55	180	2,125	780	3,950
3.1	420	2,970	1,676	.....	.....	.....	5,800	61	210	2,275	856	4,160
3.2	465	3,100	1,767	.....	.....	.....	6,000	67	245	2,425	932	4,370
3.3	515	3,230	1,858	.....	.....	.....	6,200	74	280	2,575	1,008	4,580
3.4	570	3,360	1,949	.....	.....	.....	6,400	81	325	2,725	1,084	4,820
3.5	630	3,495	2,040	.....	.....	.....	6,600	88	370	2,875	1,160	5,060
3.6	695	3,630	2,131	128	.....	.....	6,800	95	420	3,025	1,286	5,300
3.7	765	3,765	2,222	146	.....	.....	7,000	102	470	3,175	1,312	5,575
3.8	845	3,900	2,313	167	.....	.....	7,250	109	525	3,325	1,388	5,850
3.9	935	4,040	2,404	190	.....	.....	7,500	116	580	.....	1,464	6,125
4.0	1,020	4,180	2,495	216	.....	.....	7,750	124	640	.....	1,540	6,400
4.2	1,202	4,460	2,677	287	.....	.....	8,300	140	780	.....	1,692	7,000
4.4	1,384	4,750	2,859	390	.....	.....	8,900	156	920	.....	1,844	7,600
4.6	1,566	5,040	3,041	510	330	.....	9,550	173	1,060	.....	1,996	8,320
4.8	1,748	5,340	3,223	652	370	.....	10,250	194	1,210	.....	2,148	9,060
5.0	1,930	5,650	3,405	812	437	.....	10,950	219	1,370	.....	2,300	9,800
5.2	.....	5,970	3,587	972	533	.....	11,650	247	1,530	.....	2,452	10,540
5.4	.....	6,300	3,769	1,132	690	.....	12,400	275	1,690	.....	2,604	11,280
5.6	.....	6,640	3,951	1,292	850	.....	13,200	303	1,860	.....	2,756	12,020
5.8	.....	.....	4,133	1,454	1,010	.....	14,000	.....	2,030	.....	2,908	12,760
6.0	.....	.....	4,315	1,616	1,170	.....	14,820	.....	2,210	.....	3,060	13,500
6.2	.....	.....	4,497	1,780	1,330	.....	15,720	.....	2,390	.....	3,218	14,240
6.4	.....	.....	4,679	1,950	1,490	.....	16,660	.....	2,575	.....	3,376	14,980
6.6	.....	.....	.....	2,120	1,650	72	17,600	.....	2,766	.....	3,534	15,720
6.8	.....	.....	.....	2,290	1,810	100	18,540	.....	2,958	.....	3,692	16,460
7.0	.....	.....	.....	2,460	1,970	130	19,480	.....	3,150	.....	3,850	17,200
7.2	.....	.....	.....	2,630	2,130	170	20,420	.....	.....	.....	.....	17,940
7.4	.....	.....	.....	2,800	2,290	210	21,360	.....	.....	.....	.....	18,680
7.6	.....	.....	.....	2,970	2,450	250	22,300	.....	.....	.....	.....	19,420
7.8	.....	.....	.....	3,140	.....	295	23,240	.....	.....	.....	.....	.....
8.0	.....	.....	.....	3,310	.....	345	24,180	.....	.....	.....	.....	.....
8.5	.....	.....	.....	.....	.....	470	26,530	.....	.....	.....	.....	.....
9.0	.....	.....	.....	.....	.....	595	28,880	.....	.....	.....	.....	.....
9.5	.....	.....	.....	.....	.....	730	31,230	.....	.....	.....	.....	.....
10.0	.....	.....	.....	.....	.....	880	33,580	.....	.....	.....	.....	.....

Rating tables for stations in Idaho, Washington, Montana, and Oregon.

[Number in box head refers to page in Water-Supply and Irrigation Paper No. 38.]

Gage height in feet.	Discharge in second-feet.											
	359. Weiser River at Weiser, Idaho.	360. Palouse River at Hooper, Washington.	362. Big Blackfoot River at Bonner, Montana, Jan. 1 to June 30.	362. Big Blackfoot River at Bonner, Montana, July 1 to Dec. 31.	363. Rattlesnake Creek at Missoula, Montana.	364. Missoula River at Missoula, Montana, rod No. 3.	368. Bitterroot River at Missoula, Montana.	369. Spokane River at Spokane, Washington.	372. Naches River at North Yakima, Washington.	373. Yakima River at Union Gap, Washington.	375. Yakima River at Kiona, Washington.	376. Umatilla River at Gibbon, Oregon.
0.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	59
0.1	.....	.....	720	.....	.....	.....	.....	.....	.....	.....	.....	65
0.2	.....	.....	740	.....	.....	.....	.....	.....	.....	.....	.....	74
0.3	.....	.....	760	.....	.....	.....	.....	.....	.....	.....	.....	83
0.4	.....	.....	780	.....	.....	.....	.....	.....	.....	.....	.....	92
0.5	75	.....	800	865	.....	.....	.....	.....	.....	.....	.....	106
0.6	105	.....	825	890	.....	.....	.....	.....	.....	.....	.....	124
0.7	140	.....	850	940	.....	.....	.....	.....	.....	.....	.....	146
0.8	175	.....	875	990	.....	.....	.....	.....	.....	.....	.....	172
0.9	215	.....	900	1,050	.....	.....	.....	.....	.....	.....	.....	202
1.0	260	.....	950	1,110	.....	.....	.....	1,341	.....	.....	.....	233
1.1	310	.....	1,000	1,170	.....	.....	.....	1,474	.....	.....	.....	264
1.2	360	.....	1,060	1,240	.....	.....	910	1,611	.....	.....	.....	298
1.3	415	.....	1,120	1,310	.....	.....	960	1,752	.....	.....	.....	334
1.4	470	20	1,185	1,380	.....	.....	1,010	1,897	.....	.....	.....	372
1.5	530	22	1,250	1,460	.....	.....	1,080	2,046	.....	.....	.....	412
1.6	595	26	1,340	1,540	.....	.....	1,165	2,199	.....	.....	.....	454
1.7	660	32	1,440	1,630	.....	.....	1,255	2,356	.....	.....	.....	498
1.8	730	40	1,550	1,720	.....	.....	1,350	2,517	.....	.....	.....	544
1.9	800	50	1,670	1,820	.....	.....	1,445	2,682	.....	.....	.....	592
2.0	875	61	1,800	1,930	.....	.....	1,540	2,851	.....	.....	.....	642
2.2	1,025	86	2,050	2,160	.....	.....	1,730	3,201	.....	.....	.....	748
2.4	1,200	115	2,305	2,430	40	.....	1,930	3,566	.....	.....	.....	862
2.6	1,385	148	2,575	2,730	49	.....	2,160	3,946	.....	.....	.....	984
2.8	1,580	185	2,860	3,050	62	.....	2,410	4,340	.....	.....	.....	1,114
3.0	1,780	226	3,180	3,370	87	.....	2,680	4,749	.....	.....	.....	1,252
3.2	2,000	271	3,540	3,690	120	.....	2,960	5,172	.....	.....	.....	1,398
3.4	2,220	320	3,925	4,040	163	1,690	3,260	5,609	.....	.....	.....	1,552
3.6	2,450	377	4,400	4,450	220	1,800	3,570	6,059	.....	.....	566	1,714
3.8	2,690	446	4,900	4,900	295	2,000	3,890	6,523	.....	.....	663	1,884
4.0	2,940	525	5,400	5,400	385	2,240	4,230	7,000	.....	600	780	2,061
4.2	3,200	620	5,904	.....	490	2,500	4,600	7,489	.....	800	917	2,245
4.4	3,460	735	6,408	.....	623	2,800	5,000	7,990	.....	1,000	1,074	2,435
4.6	3,720	866	6,912	.....	777	3,100	5,440	8,503	.....	1,230	1,252	2,633
4.8	3,980	998	7,416	.....	931	3,500	5,910	9,028	.....	1,480	1,468	2,839
5.0	4,240	1,130	7,920	.....	1,085	3,900	6,400	9,565	.....	1,730	1,705	3,052
5.2	4,500	1,262	8,424	.....	1,239	4,400	6,930	10,114	.....	2,000	1,962	3,272
5.4	4,760	1,394	8,928	.....	1,393	4,900	7,500	10,673	.....	2,300	2,240	3,498
5.6	5,020	1,526	9,432	.....	1,547	5,400	8,100	11,243	500	2,600	2,534	3,730
5.8	5,280	1,658	9,936	.....	1,701	6,000	8,700	11,824	700	2,900	2,842	3,970
6.0	5,540	1,790	10,440	.....	1,855	6,600	9,300	12,416	950	3,200	3,160	4,217
6.2	5,800	1,922	10,944	.....	2,009	7,300	9,900	13,019	1,200	3,500	3,490	.....
6.4	6,060	2,054	11,448	.....	.....	8,000	10,500	13,631	1,500	3,900	3,834	.....
6.6	6,320	2,186	11,952	.....	.....	8,700	11,100	14,253	1,800	4,300	4,190	.....
6.8	6,580	2,318	12,456	.....	.....	9,400	11,700	14,885	2,150	4,750	4,556	.....
7.0	.....	2,450	12,960	.....	.....	10,200	12,300	15,525	2,500	5,200	4,935	.....
7.5	.....	2,780	14,220	.....	.....	12,200	14,075	17,160	3,450	6,650	5,935	.....
8.0	.....	3,110	15,480	.....	.....	14,700	16,000	18,845	4,550	8,400	6,995	.....
8.5	.....	3,440	16,740	.....	.....	17,200	18,150	20,577	5,800	10,150	8,120	.....
9.0	.....	3,770	18,000	.....	.....	20,200	20,500	22,351	7,300	12,030	9,320	.....
9.5	.....	4,100	.....	.....	.....	24,000	23,050	24,165	8,800	14,180	10,614	.....
10.0	.....	4,430	.....	.....	.....	28,350	25,900	26,012	.....	16,510	12,045	.....
11.0	.....	5,090	.....	.....	.....	.....	33,500	29,787	.....	21,690	15,045	.....
12.0	.....	5,750	.....	.....	.....	.....	42,250	33,653	.....	27,550	18,045	.....
13.0	.....	6,410	.....	.....	.....	.....	.....	.....	.....	.....	21,045	.....
14.0	.....	7,070	.....	.....	.....	.....	.....	.....	.....	.....	24,045	.....

Rating tables for stations in Oregon, Washington, and California.

[Number in box head refers to page in Water-Supply and Irrigation Paper No. 38 or No. 39.]

Gage height in feet.	Discharge in second-feet.											
	377. Deschutes River at Moro, Oregon.	380. Hood River at Tucker, Oregon.	381. White River at Buckley, Washington.	383. Dungeness River at Dungeness, Washington.	384. Elwha River at McDonald, Washington.	386. Calowa River at Forks, Washington.	386. Solduck River at Quillayute, Washington.	387. Sacramento River at Jellys Ferry, California.	391. Stanislaus River at Oakdale, California.	393. Tuolumne River at Lagrange, California.	395. San Joaquin River at Herndon, California.	405. Kings River at Red Mountain, California.
0.0	.....	.....	.....	.....	.....	130 [a]	.....	.....	.....	.....	.....	.....
0.2	.....	.....	.....	.....	.....	180	.....	.....	.....	.....	.....	.....
0.4	.....	.....	.....	.....	.....	230	.....	.....	.....	.....	.....	.....
0.6	.....	.....	.....	.....	.....	286	.....	.....	.....	.....	.....	.....
0.8	.....	.....	.....	.....	.....	348	.....	.....	.....	.....	.....	.....
1.0	5,000	.....	900	.....	.....	410	.....	.....	.....	.....	.....	.....
1.2	5,100	.....	930	.....	.....	474	220	.....	.....	.....	.....	.....
1.4	5,200	.....	960	.....	485	538	260	.....	.....	.....	.....	.....
1.6	5,330	486	1,070	.....	510	604	310	.....	.....	.....	.....	.....
1.8	5,500	560	1,225	.....	550	672	360	.....	.....	.....	.....	.....
2.0	5,750	642	1,500	.....	615	740	420	.....	.....	.....	.....	.....
2.2	6,240	732	1,900	.....	710	816	490	.....	.....	.....	60	.....
2.4	6,800	830	2,300	186	840	892	560	.....	.....	.....	100	.....
2.6	7,360	936	2,700	190	1,000	974	630	.....	.....	.....	170	.....
2.8	7,920	1,050	3,100	197	1,165	1,062	700	.....	.....	.....	280	.....
3.0	8,480	1,172	3,500	205	1,345	1,150	770	.....	.....	.....	445	.....
3.2	9,040	1,302	3,900	220	1,535	1,254	850	.....	.....	.....	640	.....
3.4	9,600	1,440	4,300	255	1,725	1,358	930	.....	.....	0	850	.....
3.6	10,160	1,586	4,700	310	1,920	1,472	1,010	.....	.....	15	1,060	180
3.8	10,720	1,730	5,100	382	2,120	1,596	1,090	.....	.....	45	1,285	250
4.0	11,280	1,900	5,500	480	2,320	1,720	1,180	2,400	.....	85	1,520	320
4.2	11,840	2,110	5,900	585	2,520	1,876	1,270	2,670	50	140	1,765	400
4.4	12,400	2,360	6,300	700	2,720	2,032	1,360	2,970	90	250	2,030	480
4.6	12,960	2,550	6,700	820	2,920	2,212	1,460	3,290	175	410	2,315	572
4.8	13,520	2,850	7,100	940	3,120	2,416	1,570	3,630	265	570	2,620	676
5.0	14,080	3,150	7,500	1,060	3,320	2,620	1,690	3,980	370	750	2,940	780
5.2	.....	3,450	7,900	1,180	3,520	2,880	1,810	4,360	485	950	3,275	908
5.4	.....	3,750	8,300	1,300	3,720	3,226	1,940	4,760	620	1,180	3,620	1,036
5.6	.....	4,050	8,700	1,420	3,920	3,586	2,080	5,170	760	1,440	3,985	1,170
5.8	.....	4,350	9,100	1,540	4,120	3,808	2,240	5,590	900	1,740	4,370	1,310
6.0	.....	4,650	9,500	1,660	4,320	4,080	2,400	6,030	1,045	2,080	4,775	1,450
6.5	.....	5,400	.....	1,960	4,820	4,760	2,810	7,265	1,450	3,100	5,850	1,930
7.0	.....	6,150	.....	2,260	5,320	5,440	3,260	8,630	1,925	4,320	7,090	2,450
7.5	.....	6,900	.....	2,560	5,820	6,120	3,760	10,100	2,450	5,760	8,410	3,120
8.0	.....	7,650	.....	2,860	6,320	6,800	4,260	11,600	3,020	7,400	9,780	3,920
8.5	.....	8,400	.....	3,160	6,820	7,480	4,760	13,100	3,625	9,000	11,060	4,870
9.0	.....	9,150	.....	3,460	7,320	8,160	5,260	14,600	4,250	10,600	12,400	6,000
9.5	.....	9,900	.....	.....	7,820	8,840	5,760	16,100	4,887	12,200	13,750	7,800
10.0	.....	10,650	.....	.....	8,320	9,520	6,260	17,600	5,525	13,800	15,110	8,800
11.0	.....	12,150	.....	.....	.....	10,880	7,260	20,800	6,800	17,000	.....	11,800
12.0	.....	.....	.....	.....	.....	.....	8,260	24,400	8,075	20,200	.....	14,800
13.0	.....	.....	.....	.....	.....	.....	9,260	28,400	9,350	23,400	.....	17,800
14.0	.....	.....	.....	.....	.....	.....	.....	32,400	10,625	.....	.....	20,800
15.0	.....	.....	.....	.....	.....	.....	.....	36,800	11,900	.....	.....	.....
16.0	.....	.....	.....	.....	.....	.....	.....	41,600	13,175	.....	.....	.....
17.0	.....	.....	.....	.....	.....	.....	.....	46,600	.....	.....	.....	.....
18.0	.....	.....	.....	.....	.....	.....	.....	52,300	.....	.....	.....	.....
19.0	.....	.....	.....	.....	.....	.....	.....	58,200	.....	.....	.....	.....
20.0	.....	.....	.....	.....	.....	.....	.....	64,200	.....	.....	.....	.....
22.0	.....	.....	.....	.....	.....	.....	.....	76,800	.....	.....	.....	.....
24.0	.....	.....	.....	.....	.....	.....	.....	90,000	.....	.....	.....	.....
26.0	.....	.....	.....	.....	.....	.....	.....	103,200	.....	.....	.....	.....
28.0	.....	.....	.....	.....	.....	.....	.....	116,400	.....	.....	.....	.....
30.0	.....	.....	.....	.....	.....	.....	.....	129,600	.....	.....	.....	.....
32.0	.....	.....	.....	.....	.....	.....	.....	142,800	.....	.....	.....	.....
34.0	.....	.....	.....	.....	.....	.....	.....	156,000	.....	.....	.....	.....

[a] Continued: Gage height −0.1, discharge 105; gage height −0.2, discharge 80; gage height −0.3, discharge 60; gage height −0.4, discharge 40; gage height −0.5, discharge 30; gage height −0.6, discharge 20; gage height −0.7, discharge 10.

ERRATA IN VARIOUS PUBLICATIONS.

In preparing for publication the results of field work for 1899 frequent reference has been made to earlier publications and a number of errors have been discovered. Some of these are of relatively little importance, but they are noted in the interest of accuracy. The following list gives corrections which can be made in various Annual Reports and in Water-Supply and Irrigation Papers.

Water-Supply and Irrigation Paper No. 15:

Page 51, tenth line from bottom, for 20 miles read 11 miles.

Page 85, in table of daily gage heights, May 25, for 7.72 read 4.72.

Water-Supply and Irrigation Paper No. 16:

Page 190, in table of daily gage heights, December 23 and 24, for 2.11 read 2.92.

Water-Supply and Irrigation Paper No. 33:

Page 62, third line from top, for 57 cubic yards read 5.7 cubic yards.

Page 65, eleventh line from top, for 206,000 read 119,000.

Page 65, nineteenth line from top, for 344,398 read 344,308.

Water-Supply and Irrigation Paper No. 36:

Page 107, third line from top, for Danville read Clarksville.

Eighteenth Annual Report, Part IV:

Page 19, ninth line from top, for Conoloway Creek, read Tonoloway Creek.

Page 30, in list of discharge measurements, March 25, 1895, under area of section, for 10,524 read 6,257; July 10, 1895, under area of section, for 4,695 read 4,118; for November 16, 1895, read November 6, 1895.

Page 39, fifth line from top, before Staunton insert Natural Bridge.

Page 43, in list of discharge measurements, deduct 0.53 from all gage heights for 1896.

Page 45, in list of discharge measurements, under gage heights, for .0.07 read −0.07; for 3.43 read 1.37; for 3.20 read 0.97; for 4.70 read 2.06; for 2.00 read 0.04.

Page 65, drainage area of Catawba River at Catawba, North Carolina, for 3,492 read 1,535.

Page 113, last three lines, the description of the bench marks refers to the Alderson, West Virginia, station, and not to the Fayette, West Virginia, station.

Page 119, twenty-eighth line from top, for Como read Cowee.

Page 221, in rating table for Kansas River for 1895, opposite gage height 2.60, for 9,440 read 9,340.

Page 283, at top of page, drainage area of Piedra River, for 650 read 670.

Page 351, in list of discharge measurements, under gage height, opposite August 7, 1896, for 1.45 read 1.92.

Page 368, shift all figures at bottom of diagram one space to the left.

Nineteenth Annual Report, Part IV:

Page 319, middle of page, drainage area of Boulder Creek, for 102 read 179.

Page 333, last line of text, for Middle Loup River read Loup River.

Page 349, in footnote, for 1896 read 1895.

Page 514, fig. 184, the February flood should reach to 13,200.

Page 515, in table of estimated monthly discharge of San Joaquin River, the minimum for December (60) should read 535, and the minimum for the year should read 105 instead of 60.

Twentieth Annual Report, Part IV:

Page 165, the figures on the left of the hydrograph for Savannah River, except 0, should be moved up one division. Insert 5,000 opposite the first division.

Page 211, the figures on the left of the hydrograph for Tennessee River should all be multiplied by 10.

Page 286, middle of page, drainage area of Boulder Creek, 102 square miles should read 179 square miles.

Page 410, sixteenth line from bottom, for 402 read 404.

Page 485, footnote refers to measurements in table on ninth and second lines from bottom only.

INDEX TO PAPERS NOS. 35 TO 39.

[The Water-Supply and Irrigation Papers are limited by law to 100 pages each. It was therefore necessary to divide the report on the operations at river stations for 1899 into five parts. Paper No. 35 contains pages 1 to 100; Paper No. 36, pages 101 to 198; Paper No. 37, pages 199 to 298; Paper No. 38, pages 299 to 396; Paper No. 39, pages 397 to 471.]

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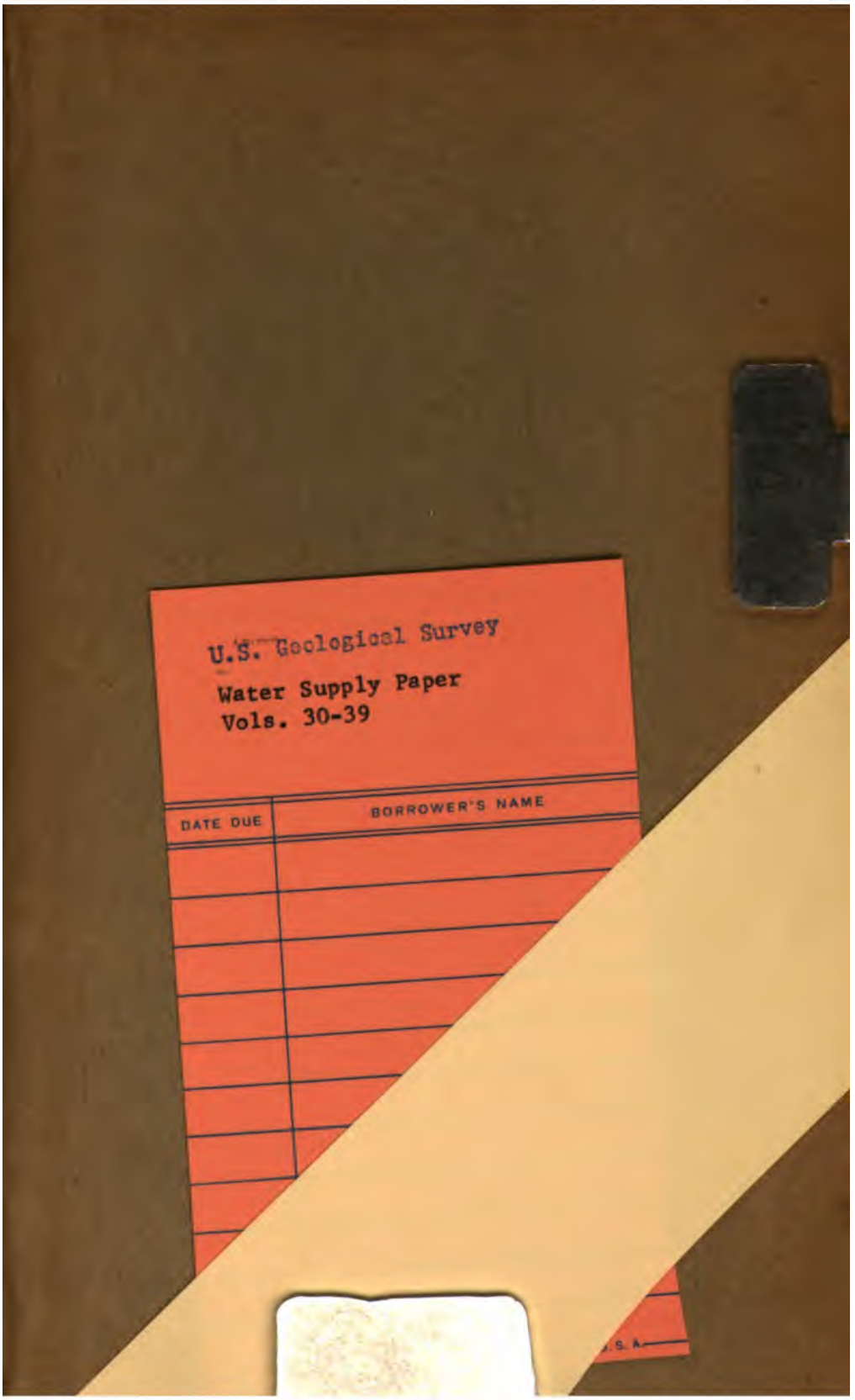
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